SER1CH-UA User Manual

Manual Revision (2007/11/25)

Board Revision B

Symmetric Research
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FREE WEB VERSION - PARTIAL CIRCUIT DIAGRAMS

Contents

List of Figures

Chapter 1

Introduction

The Symmetric Research SER1CH-UA is a precision analog to digital converter for DC applications requiring 24 bit A/D conversions at a 1Hz sampling rate. In addition to its high resolution, the system also has very low power consumption. With an active power requirement of only 600 microamperes at 9 volts, it can be easily powered from batteries or solar cells for field applications.

Along with an analog input for A/D conversions, a buffered copy of the A/D reference is also provided for the user. This is useful for ratiometric applications, such as measuring potentiometer positions and other sensor values. By using the same reference voltage for the sensor and A/D, measurement variations due to temperature drift are virtually eliminated.

The digital interface is to a PC RS232 serial port. Software access is from user space without the need for a kernel mode device driver. A Windows GUI DVM application is included for displaying conversion results as well as saving acquired data to a hard disk. Easy to use, the system requires power from a wall transformer or battery, connection to the user's sensor, and a PC. Among the features of the SER1CH-UA are:

- 24 bit one channel A/D converter design for DC measurements
- Low power consumption, 600 microamperes during conversion
- Power supply voltage can range from 9 to 18 volts
- Buffered analog input with 10M ohm input impedance
- Buffered A/D reference voltage provided for ratiometric measurements
- General use includes applications with potentiometers and other passive sensors
- Banana input plugs, test leads, wall transformer, and software included

We hope the SER1CH-UA is a useful tool for your applications

Typical usage:

One popular SER1CH-UA setup is with a potentiometer for measuring angular or linear position. The photo below shows a ratiometric connection, where the SER1CH-UA provides the potentiometer excitation with its VREF jack. No other equipment is required. This particular potentiometer is a 10 turn device. The connections are the same for other types of potentiometers. See the Examples and Experiments chapter for a more detailed discussion.

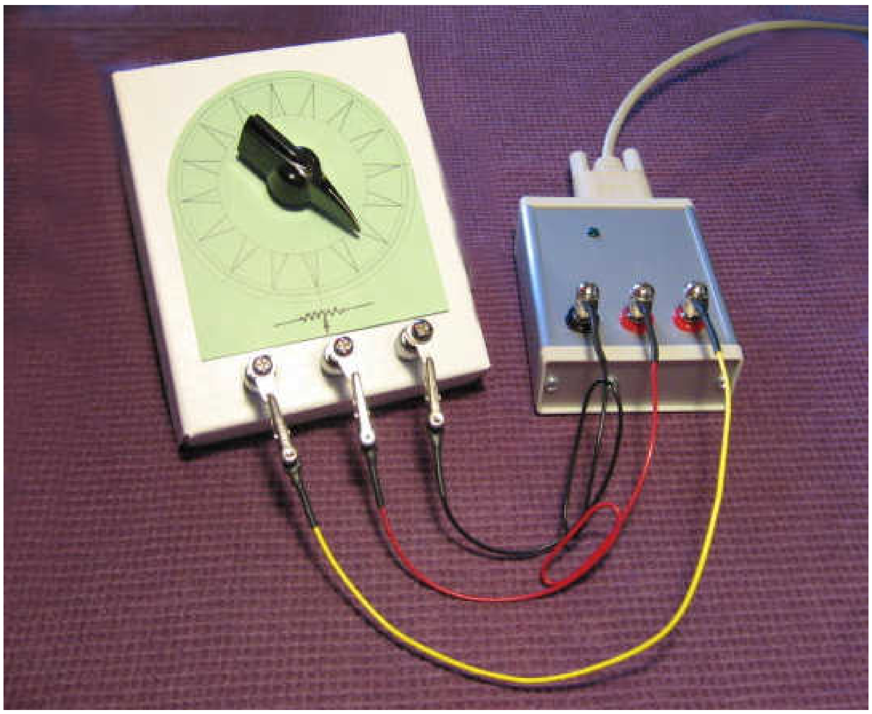


Figure 1.1: SER1CH-UA with typical potentiometer setup

Many other types of passive and active sensors requiring DC measurements at a 1Hz sampling rate can also be used. Strain gauges, photocells, and pressure sensors are a few examples. With an input impedance of 10M ohms the system adds only a very light load to whatever it is connected to.

The setup shown here is powered from a single 9 volt battery. With its low power consumption, the system can run for long periods from small power sources. Also, besides the banana jack version of the SER1CH-UA, other models with Dshell connectors for front and back panel connections, and a narrow 1 inch wide model with inline headers for borehole applications are also available.

Chapter 2

Getting started

Installation of the SER1CH-UA is straightforward. Here are the steps to follow:

2.1 Hardware installation

Connect the SER1CH-UA to the supplied wall transformer with the 2.1mm power connector. The green power LED on the top panel should light up. If not, make sure the wall transformer has power. Then connect the RS232 DB9 on the SER1CH-UA back panel to your PC with the supplied 6 ft cable. Make a note of which COM port you are using on your computer. You will need to know the COM number when running the application software.

Analog connections are made to the three banana jacks on the top panel of the SER1CH-UA. Reading from left to right, the jacks are (GND, VIN, VREF) with the colors (black, red, red) as in Figure 2.1.

The middle red banana jack is the VIN analog input. *All voltages are measured with respect to GND*, the black banana jack. When you are connecting an external voltage use the VIN and GND banana jacks to connect the voltage, *keeping in mind the GND jack is the same as PC system ground*.

The outer right red banana jack is the VREF output jack. Don't connect the VREF jack directly to ground. It is not fatal, but will draw unnecessary current.

For initial testing connect the VIN jack to the GND or VREF to place known voltages on the analog input as in the following figures. When connecting VIN to VREF, you don't need to make a connection to GND because the VIN and VREF share the same ground internally.

Figure 2.1: VIN connected to VREF

Figure 2.2: VIN connected to GND

2.2 Software installation

Run the install.bat file on the CD. The directory /SR/SER1CH-UA will be created on your hard disk and files will be copied there. No changes will be made to the operating system registry or any other system files.

The SER1CH-UA does not require a device driver or device driver installation. Application programs such as DvmGui.exe may be run as soon as the SER1CH-UA is connected to a serial port and the SER1CH-UA is powered up.

To uninstall the software, simply delete the /SR/SER1CH-UA directory.

2.3 Do's and Don'ts

- **DO** use the provided 9 vdc wall transformer or a 9 volt battery to power the system.
- **DO** use the system with RS232 ports that support RTS, DTR, and CTS.
- **DO** read the FAQ chapter for general questions regarding the SER1CH-UA.
- **DO** use the SER1CH-UA to measure positive voltages in the (0,5) volt range on the red VIN banana jack with respect to the black GND banana jack.

- **DON'T** exceed 18 volts on the power supply. Excessive power supply voltages will result in high power supply current drain.
- **DON'T** expect to make precision measurements with floating inputs. The analog input VIN must be connected to a voltage source to make an accurate measurement. VREF and GND are convenient voltages for initial testing.
- **DON'T** short circuit the VREF A/D reference output banana jack to the black GND jack. The output is current limited so no damage will occur, however any current sourced by VREF is ultimately provided by the SER1CH-UA power supply.
- **DON'T** use the SER1CH-UA to measure 110 vac or other high voltages. You will damage the system and perhaps even your computer.

Chapter 3

Application Programs

The SER1CH-UA comes with two finished application programs, DVM and CAL. With these programs, you can acquire data, display it on the screen, save it to disk, and calibrate the system. Even for those planning to write their own custom software, running these programs will help you quickly understand how the system works.

The DVM program displays its data on the screen in familiar digital voltmeter style with large green readouts that are easy to see. Even though the SER1CH-UA has only one channel, there are two readouts of the same data that can each be calibrated into different display units. So, for example one readout could display sensor volts, while the other displays physical sensor units. There is also a command line only version of DVM if you don't want the GUI display.

The CAL program is useful for gathering calibration coefficients for the DVM program. Not only can it provide absolute calibration for the system, it can also easily calibrate into physical units for the DVM readouts.

These programs can be found in subdirectories of /SR/SER1CH-UA. If you wish to run with predefined configurations, there are shortcuts that can be double clicked to run immediately. Further information about configuring and running these programs is given in the following sections.

- ▷ DVM — enhanced dual readout digital voltmeter
- ▷ CAL — DVM calibration into volts and user units

3.1 DVM

DVM is a program with a display and function much like a digital voltmeter. If instruments such as Fluke meters are familiar, then you will find DVM easy to use.

There are two versions of DVM, a GUI version with graphical display, and a command line console mode version. The GUI version is available only for Windows, while the command line version is available for both Windows and Linux. When up and running the GUI version will look like:

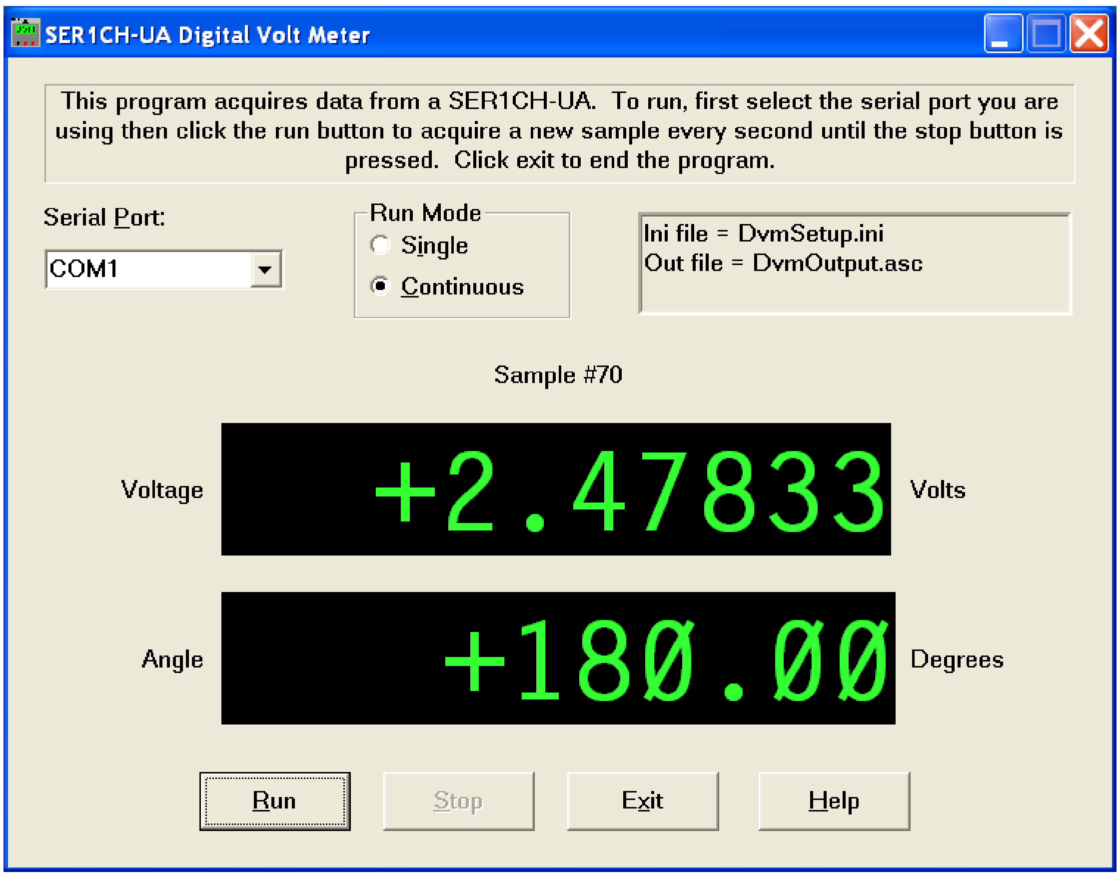


Figure 3.1: Screen shot of GUI version of DVM program

A feature of DVM is although the SER1CH-UA only has one acquisition channel, DVM has two separate readouts. The same data can be displayed twice, but scaled into different units. This can be useful for example if you would like to monitor the voltage from a sensor *and display physical sensor measurement units* at the same time. In the display above, the first readout shows sensor units as volts, while the second display shows the physical

sensor reading, in this case an angle is shown as might occur with a potentiometer. Both displays are generated from the raw A/D counts by applying a simple linear scale and offset transformation.

A few DVM options can be specified on the GUI screen. For example, if the RunMode Single radio button is selected, a single data sample will be acquired each time the Run button is pressed. If Continuous is selected, DvmGui will acquire data at a 1Hz rate until the Stop button is pressed.

Many other options can be specified in the DVM ini file. Both the GUI and command line versions use the same ini syntax. For example, one ini option is to specify an output data file. That way acquired values are displayed on the screen in real time and also saved to disk. See the ASC output file section for more information about the format. Note that while the output filename is displayed on the GUI screen for information, it is specified in the ini file.

Besides saving data to disk, DVM *can also record the time at which the each data sample was acquired*. The PC clock is used as a time source, and the timestamps can be saved in a variety of formats. See the DVM: ini syntax section for the possible choices.

3.1.1 DVM: starting the program

Starting DVM is similar for either the GUI or text only console mode versions. From the command line type:

```
cmd:prompt>  DvmGui parameters.ini

cmd:prompt>  DvmCmd parameters.ini
```

where the first is for the GUI display and the second for the text only display. The parameters.ini file is optional. If not specified, DVM will start up with defaults. If you want to run with custom parameters, they should be specified in the ini file. There is nothing special about the ini filename, any filename may be used. In fact, having several ini files for different setups can be very handy.

Several program shortcuts are also included in the DVM directory for quick starts. Double click on them to execute. Copy the shortcuts to the desktop or start menu for easy access if needed. You can also make multiple copies of the shortcuts and edit their properties to run with different ini setups.

If no ini file is specified, DVM will create an ini file named DvmSetupDefault.ini containing the default settings. Copy this file to a new name and modify it to have the settings you prefer.

Once DvmGui.exe starts, its display window shows the RS232 serial port it will use. If this port selection is not correct, select the serial port that the SER1CH-UA is connected to from the pull down list, and click the Run button to begin acquiring data. You will probably want to edit your ini file so the program starts up with the correct port in the future. Also see the section determining the serial port for a discussion about how to choose a valid serial port.

In the case of the DvmCmd.exe console version of the program, at startup it displays a prompt showing the serial port it will use. If this is not correct, edit the ini file and try again. Once the serial port selection is correct, press the ENTER key to begin acquiring data.

3.1.2 DVM: determining the correct serial port

For DVM (and CAL) to run correctly, it is important to select the serial port which is actually connected to the SER1CH-UA. The Windows Device Manager can help narrow down the choices by showing which ports are even available.

The Device Manager can be accessed graphically from the Control Panel or from MyComputer properties. It can also be accessed from a command prompt by typing devmgmt.msc and pressing ENTER.

Once the Device Manager window is showing, open or expand the Ports (COM & LPT1) class. The available serial ports are listed as Communications Port (COMx). Some additional COM ports may be assigned to other devices such as modems, but these will not be listed in the Ports class and can not be used with the SER1CH-UA.

After identifying the possible port selections in Device Manager, you can run DvmGui.exe to test them out. Use an alligator clip to connect the SER1CH-UA VREF from the red outer banana jack to the red VIN banana jack in the middle. This provides a known voltage of about 4.96v to the SER1CH-UA A/D input. Then select one of the possible serial ports in the DvmGui.exe dropdown list and click the run button. If you see the voltage display showing 4.96 volts and the acquired sample number incrementing then you have the right serial port. If not, click the stop button and repeat with the next serial port in the DVM list you want to try.

3.1.3 DVM: ini syntax

The layout of a DVM ini file is free format ASCII with a simple syntax of the form:

```
keyword = value
```

Comments are denoted with a semicolon, where everything from ; to the end of line is a comment. Use text editors such as Windows Notepad or any other favorite to create and edit ini files. For a listing of all the DVM ini keywords, see the file:

```
/SR/UsbXch/Dvm/DvmHelpIniSyntax.txt
```

Keywords not specified in the ini file will be given default values. Here is an example of a short ini file:

```
; General parameters:

SerialPortName         = COM1
OutputFileName         = "DvmOutput.asc"
OutputFileComment      = "Example ini showing volts and degrees"
OutputFileShowTimeSec  = ON
RunMode                = CONTINUOUS

; Display 0 format and calibration parameters:

DisplayTitle  0 = "Voltage"
DisplayUnits  0 = "Volts"
DisplayPlaces 0 = 9
DisplayDigits 0 = 5
DisplaySlope  0 = 2.98511e-007
DisplayOffset 0 = -0.00119882

; Display 1 format and calibration parameters:
; Angular position with full range calibrated from 0 to 360.

DisplayTitle  1 = "Angle"
DisplayUnits  1 = "Degrees"
DisplayPlaces 1 = 6
DisplayDigits 1 = 2
DisplaySlope  1 = 2.16764e-005
DisplayOffset 1 = -0.0536708
```

Figure 3.2: Sample DVM ini initialization file

For reference, the following table describes many of the DVM ini keywords. Also refer to the help file `DvmHelpIniSyntax.txt` for the most current list.

DVM ini Keywords

Keyword	**Description**	**Values**
`SerialPortName`	Name of serial port to use	COM1, COM2, COM3, COM4
OutputFileName	Name of file for saved data	File name in quotes like "DvmOutput.asc"
OutputFileComment	Arbitrary text to help identify the saved data	Descriptive comment in quotes like "Test 4"
OutputFileShowHeader	Switch controlling whether output file includes headers	ON, OFF
OutputFileShowIndex	Switch controlling whether output file includes sample num	ON, OFF
OutputFileShowTimeSec	output time as seconds since 1970	ON, OFF
`OutputFileShowTimeYmd`	Output time as YMDHMS	ON, OFF
`RunMode`	Sampling mode	SINGLE, CONTINUOUS

Keywords specific to display readout `N = (0,1)`:

`DisplayTitle    N`	Title	String like "Voltage"
`DisplayUnits    N`	Units	String like "Volts"
`DisplayPlaces   N`	Total number of digits	Integer like 9
`DisplayDigits   N`	Digits after decimal point	Integer like 5
`DisplaySlope    N`	Calibration slope	Float like 7.27444e-007
`DisplayOffset   N`	Calibration offset	Float like 0.0000953873

Figure 3.3: DVM ini keyword table

3.1.4 DVM: calibrating the readouts

Now you should see the data acquired from the single SER1CH-UA channel being displayed twice on the dialog box. These two displays represent the same data scaled into different units. For example, the first display could show volts while the second display could show user units such as inches or degrees or ounces or etc depending on the specific type of sensor being used. Both displays are generated from the raw data, which comes in as A/D counts, by applying a simple linear scale and offset transformation.

This transformation is really nothing more than using the familiar $y = mx + b$ equation for a straight line where the scale factor m and the offset b are controlled by user settable calibration parameters located in the DVM .ini initialization file. The easiest way to determine the proper parameter values is to use the CAL program.

3.1.5 DVM: ASC output file format

Both the GUI and command line versions of DVM save their acquired data to ASCII output files. Typically it is named DvmOutput.asc, but you can select the filename with the ini keyword OutputFileName. Including summary header data can be controlled with the additional OutputFileShowHeader keyword. For importing into Excel, use OutputFileShowHeader=OFF to suppress the header text and include only the data values themselves.

DVM will not overwrite an existing .asc output file. So, if you've already run DVM once, rename or delete any existing ASC output file before running DVM again. Changing the ini keyword OutputFileName will also work and reloading the initializations will work.

Now let's see what some DVM .asc output files look like. The first sample output file was created in verbose mode with all the optional outputs turned on. It has OutputFileShowHeader=ON so the header information is included and has OutputFileShowIndex=ON so a extra column with the sample number is included. In addition, it has OutputFileShowTimeSec=ON and OutputFileShowTimeYmd=ON which add columns containing time as seconds since 1970 and as year/month/day respectively.

The second sample DVM .asc output file was created in bare mode with all the optional outputs turned off so only the data values are included. This mode makes it easy for the file to be imported into analysis programs like Excel or MatLab.

```
Header:

    General File Info:
      HeaderFormatRev       = 2
      DvmRev                = 2.01
      FileName              = "DvmOutput.asc"
      FileCreationDate      = 2008/02/01 18:57:12
      IniFileName           = "DvmSetup.ini"

    Ini Parameters:
      SerialPortName        = COM1
      OutputFileName        = "DvmOutput.asc"
      OutputFileComment     = "Example ini showing volts and degrees"
      OutputFileShowHeader  = ON
      OutputFileShowIndex   = ON
      OutputFileShowTimeSec = ON
      OutputFileShowTimeYmd = ON
      RunMode               = CONTINUOUS

      DisplayTitle  0 = "Voltage"
      DisplayUnits  0 = "Volts"
      DisplayPlaces 0 = 9
      DisplayDigits 0 = 5
      DisplaySlope  0 = 2.98511e-007
      DisplayOffset 0 = -0.00119882

      DisplayTitle  1 = "Angle"
      DisplayUnits  1 = "Degrees"
      DisplayPlaces 1 = 6
      DisplayDigits 1 = 2
      DisplaySlope  1 = 2.16764e-005
      DisplayOffset 1 = -0.0536708


Data:
      Sample       Volts     Degrees    Time (Sec)        Time (YMD HMS)
           1    -0.00021       +0.02  1201892232.522  2008/02/01 18:57:12.522
           2    +1.23895      +90.00  1201892233.684  2008/02/01 18:57:13.684
           3    +2.47836     +180.00  1201892234.845  2008/02/01 18:57:14.845
           4    +3.26040     +236.79  1201892236.007  2008/02/01 18:57:16.007
           5    +4.95701     +359.99  1201892237.169  2008/02/01 18:57:17.169
           6    +2.06543     +150.01  1201892238.330  2008/02/01 18:57:18.330
           7    +0.30847      +22.43  1201892239.492  2008/02/01 18:57:19.492
```

Figure 3.4: Sample DvmOutput.asc output file in verbose mode.

```
-0.00021      +0.02
+1.23895     +90.00
+2.47836    +180.00
+3.26040    +236.79
+4.95701    +359.99
+2.06543    +150.01
+0.30847     +22.43
```

Figure 3.5: Sample DvmOutputBare.asc output file in bare mode.

3.1.6 DVM: modifying the program

For those who are comfortable programming in C/C++ and want to modify DVM, this section briefly discusses the organization of the provided source code files.

The files DvmLib.c and DvmLib.h contain the major portion of DVM, the part that is shared between both the GUI and CMD versions. The files that start with DvmGui are used for the GUI version and the file DvmCmd.c is used for the CMD version. Both versions depend on the variables and functions defined in the DvmLib files.

Both DvmGui and DvmCmd can be built from the command prompt using the provided Makefile. It accesses various settings and macros contained in the Compiler.mak file in the /SR/SER1CH-UA/Lib directory and assumes that a batch file like vsvars.bat has been run to set the compiler environment. The .sln and .vcproj files can be used to build DvmGui.exe and DvmCmd.exe from inside the Visual Studio 2005 IDE.

Please refer to the comments inside the source code files themselves for more details.

3.2 CAL

To get the most accuracy from the DVM program described in section it is important to calibrate the A/D. The CAL program makes this calibration easy. Like DVM, there are two versions of CAL. CalCmd.exe is a console program that runs from the command line while CalGui.exe is a Windows Graphical User Interface (GUI) program that uses the Microsoft Foundation Classes (MFC) libraries.

Both versions of CAL read a preliminary set of control settings from a DVM initialization file such as DvmSetup.ini in the Calibrate directory and output the calibrated version of these settings into DvmSetupCal.ini. Don't forget to copy DvmSetupCal.ini to the DVM directory and rename it before running DVM again!

Running either version of CAL is simple. From Windows Explorer, double click on the RunCalCmd or RunCalGui shortcut to start CalCmd.exe or CalGui.exe respectively. The RunCalCmd shortcut first starts a command prompt and then runs CalCmd.exe. You may also type in at a command prompt either program name followed by the name of the .ini file you wish to use. If no .ini file is specified, CAL will output a .ini file named DvmSetupDefault.ini containing the default settings. You should copy this file to a new name, modify it to have the settings you prefer, and run CAL again with the new .ini file name as a command line or shortcut argument.

Both versions of CAL require that certain information is entered and that two known input signals are presented to the SER1CH-UA for calibration measurements to be taken. The required information includes the display title (eg voltage) and name of the units to be used (eg volts), the value of one known input signal, and the value of a different known input signal. Because DVM displays the acquired data in two ways (for example in volts and in inches), appropriate calibration information is needed for both displays.

Once CalCmd.exe starts, it displays a prompt showing the serial port it will use. If this is not correct, please quit, edit the .ini file and try again. Also, see the section Selecting the serial port for a discussion about how to choose a valid serial port.

Once the serial port selection is correct and you are ready to continue, CalCmd prompts you to enter the required calibration information starting with the display titles and units. Then apply a known input signal to the SER1CH-UA, enter its value and press a key to measure it. Repeat this for a second known input signal. CalCmd then computes the calibration results and outputs them to the DvmSetupCal.ini file.

Once CalGui.exe starts, it displays a dialog box showing the default serial port specified in the .ini file. If this is not correct, use the serial port dropdown list box to select the serial port that *is* connected to the SER1CH-UA.

CalGui provides you with text boxes for entering the required calibration information like the display titles and units. To perform the actual calibration, apply a known input signal

to the SER1CH-UA, fill in the Value A text field for each display and click the MeasureA button to measure the A/D counts for that signal. Repeat with a second known input signal, Value B and the MeasureB button. The calibration results are updated each time a Measure button is pressed. Click the Save button to output the calibration results to the DvmSetupCal.ini file.

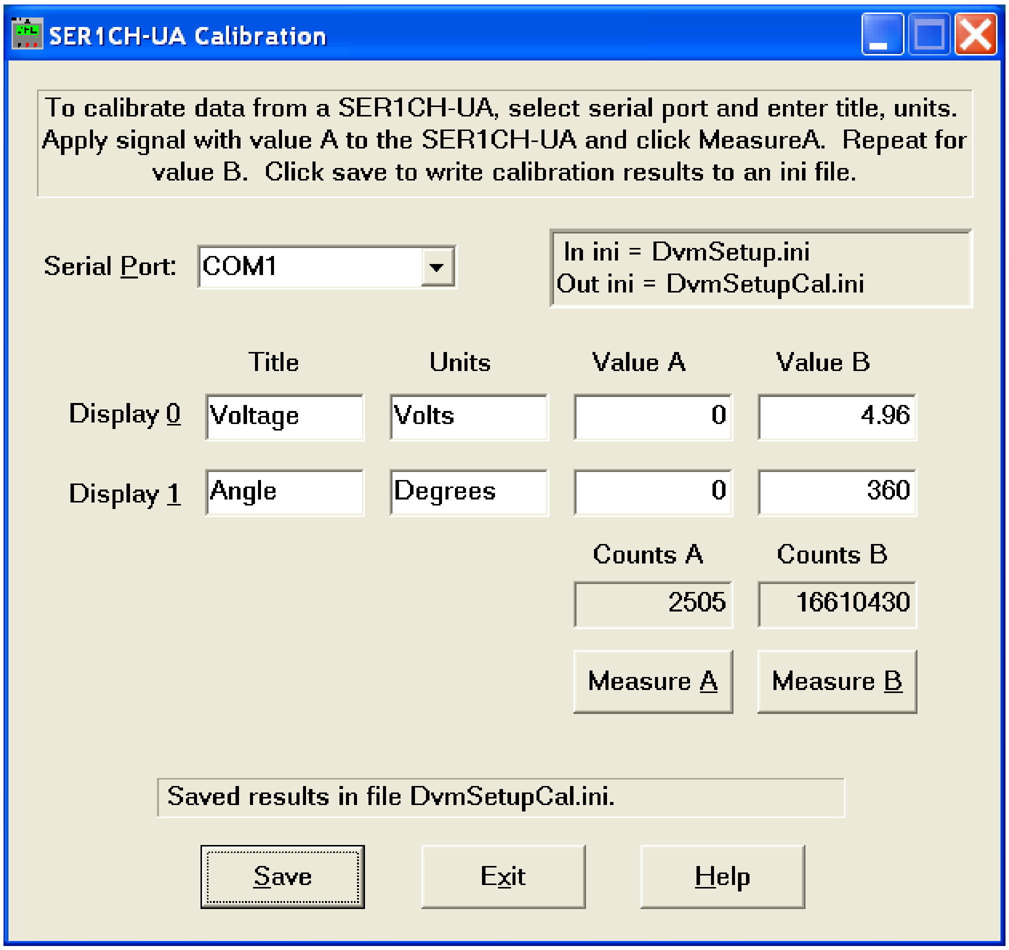


Figure 3.6: Screen shot of GUI version of CAL program

3.2.1 CAL: starting the program

Starting CAL is similar for either the GUI or text only versions. From the command line type:

```
cmd:prompt>  DvmGui parameters.ini

cmd:prompt>  DvmCmd parameters.ini
```

where the first is for the GUI display and the second for the text only display. The parameters.ini file is optional. If not specified, DVM will start up with defaults. If you want to run with custom parameters, they should be specified in the ini file. There is nothing special about the ini filename, any filename may be used. In fact, having several ini files for different setups can be very handy.

Several program shortcuts are also included in the DVM directory. Double click on them to execute. Copy the shortcuts to the desktop or start menu for easy access if needed. You can also make multiple copies of the shortcuts and edit their properties to run with different ini setups.

OLD TEXT REGARDING RUNNING . . .

If no parameters.ini file is specified, DVM will create an ini file named DvmSetupDefault.ini containing the default settings. Copy this file to a new name and modify it to have the settings you prefer.

Once DvmCmd.exe starts, it displays a prompt showing the serial port it will use. If this is not correct, edit the .ini file and try again. Also, see the Selecting the serial port section for a discussion about how to choose a valid serial port. Once the serial port selection is correct, press the ENTER key to begin acquiring data.

Once DvmGui.exe starts, it displays a dialog box showing the default serial port specified in the .ini file. If this is not correct, use the serial port dropdown list box to select the serial port that *is* connected to the SER1CH-UA. Then click the run button to begin acquiring data.

3.2.2 CAL: modifying the program

For those who want to modify CAL and are comfortable programming in C/C++, this section reviews the organization of its source code files.

The files CalLib.c and DvmLib.c are both required to build CAL. The files that start with CalGui.cpp and CalCmd.c are the additional user interface source for the GUI and CMD versions of the programs. Both versions depend on the variables and functions defined in the CalLib and DvmLib files.

Both CalGui.exe and CalCmd.exe can be built from the command prompt using the provided Makefile. It accesses various settings and macros contained in the Compiler.mak file in the /SR/SER1CH-UA/Lib directory and assumes that a batch file like vsvars.bat has been run to set the compiler environment. The .sln and .vcproj files can be used to build CalGui.exe and CalCmd.exe from inside the Visual Studio 2005 IDE.

Please refer to the comments in the source code files themselves for more details.

3.2.3 CAL: determining the correct serial port

For DVM and CAL to run correctly, it is important to select the serial port which is actually connected to the SER1CH-UA. The Windows Device Manager can help narrow down the choices by showing which ports are even available.

The Device Manager can be accessed graphically from the Control Panel or from MyComputer properties. It can also be accessed from a command prompt by typing devmgmt.msc and pressing ENTER.

Once the Device Manager window is showing, open or expand the Ports (COM & LPT1) class. The available serial ports are listed as Communications Port (COMx). Some additional COM ports may be assigned to other devices such as modems, but these will not be listed in the Ports class and can not be used with the SER1CH-UA.

Now that the possible serial ports have been identified, you can run DvmGui to test them out. Using the provided alligator clip cables, connect VREF from the red outer banana jack to VIN on the red middle banana jack. This provides a known voltage of about 4.96v to the A/D inputs.

Select one of the possible serial ports in the DvmGui dropdown list and click the run button. If you see the sample number incrementing and the voltage display showing 4.96 volts you have the right serial port. If not, click the stop button and repeat with the next serial port you want to try.

Chapter 4

User C Library

Besides finished applications like DVM and CAL, the SER1CH-UA comes with a function library for users writing their own programs. These functions can be statically linked to C programs, or called as a Dynamic Link Library (DLL) under Windows and a shared library (.so) under Linux.

The library is written in C, but can be called from languages such as Visual Basic and LabView as long as C calling conventions are followed. The methods for calling DLL functions are specific to each language and typically require declarations describing the parameters being passed. Check your language documentation for details.

The typical sequence of calls to use the library is simple: First call Open to initialize the COM serial port and A/D. Then call GetData each time you want a new A/D sample, followed by ScaleData if you want to convert the A/D counts to volts or other units. Finally, when finished, call Close to free the COM port for other programs.

Be sure to include the header file Ser1ch.h in any C source code using the library. This file contains prototypes and defined constants that can help make your program more maintainable and readable. When using dynamic linking, make sure the Ser1ch.dll library is on your Windows execution path so it can be found at runtime. Under Linux the shared library libser1ch.so should be on the LD_LIBRARY path.

The table on the following page summarizes the SER1CH-UA library functions and their parameters. Each function is also described in more detail in the following sections, along with a code fragment to show typical calls from C.

SER1CH-UA Library Function Summary

Function/Parm	IO	Type (#bits)	Description
Ser1chOpen			Open the serial port and initialize A/D
return	O	DEVHANDLE (32)	= BAD_DEVHANDLE on failure
SerialPortNumber	I	integer (32)	Serial port number 1=COM1, 2=COM2, ...
Error	O	pointer to integer (32)	Detailed error code
Ser1chGetData			Read a data point and the PC time
return	O	integer (32)	1 for success, 0 for failure
Ser1chHandle	I	DEVHANDLE (32)	Handle to SER1CH-UA serial port
DataCounts	O	pointer to integer (32)	Data point as raw A/D counts
TimeSecSince1970	O	pointer to double (64)	PC time of data point as seconds since 1970
Error	O	pointer to integer (32)	Detailed error code
Ser1chScaleData			Scale data point counts to other units
return	O	integer (32)	1 for success, 0 for failure
DataCounts	I	pointer to integer (32)	Data point as raw A/D counts
Slope	I	floating point double (64)	Slope of scaling formula
Offset	I	floating point double (64)	Offset of scaling formula
ScaledData	O	pointer to double (64)	Data point scaled to other units
Error	O	pointer to integer (32)	Detailed error code
Ser1chErrorMsg			Get string associated with error code
return	O	pointer to char (8)	Null terminated C-style string
Error	I	integer (32)	Detailed error code
Ser1chClose			Close the serial port and A/D
return	O	integer (32)	1 for success, 0 for failure
Ser1chHandle	I	DEVHANDLE (32)	Handle to SER1CH-UA serial port
Error	O	pointer to integer (32)	Detailed error code

Figure 4.1: Ser1ch library function table

In addition to standard data types like integer and pointers to integers, the table also lists DEVHANDLE. This special data type is defined in SrHelper.h and varies depending on OS. Under Windows it is a `(void *)` and is equivalent to the Windows HANDLE type. Under Linux it is an integer. In both cases, the size is 32 bits and the parameter refers to an open file handle which gives the OS a shorthand way to refer to the device.

4.1 Open device

C usage:

```
#include "Ser1ch.h"

        DEVHANDLE Ser1chOpen( int SerialPortNumber, int *Error );
```

The Open function opens and initializes the specified COM serial port and SER1CH-UA A/D. It should be the first library function called.

The first argument passed to Open is an integer from 1 to 9 that specifies the serial port to use. A value of 1 corresponds to COM1 under Windows or /dev/ttyS0 under Linux. 2 selects COM2, etc. You may want to check the Device Manager under Windows to see which COM ports are available on your machine as described in section **??** on page **??**.

The second argument is a pointer to an integer that will be filled with an error code giving some detail about the failure if one occurs. An error code of 0 means the open succeeded. This argument is optional and will be ignored and not filled in if you pass Error = NULL. See Ser1ch.h for a list of the possible error codes. Or, use the ErrorMsg function to get the message string associated with the integer error number.

Open returns a file handle to the open serial port in the form of a specially defined data type called a DEVHANDLE. Under Windows this is a `(void *)` and is equivalent to the Windows HANDLE type. Under Linux it is an integer. In both cases, the size is 32 bits and this file handle provides a shorthand way for the OS to access the selected serial port. If Open fails, the return value is BAD_DEVHANDLE which is defined as -1.

Note that under Linux, Open will fail if you don't have read permission on the selected serial port. Type the command `ls -l /dev/ttyS0` to see the current permissions on COM1. The two easiest ways to add read permission for yourself are to join the group such as `uucp` or `nut` that owns the COM port or to type the command `chmod o+r /dev/ttyS0` as root to add world read permission to the COM port.

4.2 Read data

C usage:

```
#include "Ser1ch.h"

        int Ser1chGetData( DEVHANDLE Ser1chHandle,
                           long *DataCounts,
                           double *TimeSecSince1970,
                           int *Error );
```

Once you have successfully called Open to open and initialize the serial port, you can call GetData to read in a data point as raw A/D counts.

GetData returns 1 for success and 0 for failure. It also takes an optional Error argument for returning more detailed information when a failure occurs. See Ser1ch.h for a list of the possible error codes, or use the ErrorMsg function to get the message string associated with the error number.

The first argument to GetData is the DEVHANDLE returned by Open containing a file handle to the open serial port. GetData uses this handle when deciding which serial port to read.

The DataCounts argument to GetData should be a pointer to a 32 bit long integer. The integer will be filled in with the A/D count value. The 24 bit A/D count is stored as a 32 bit integer with the top 8 bits always 0.

The optional TimeSecSince1970 argument returns the time when the A/D conversion occurred. Pass a NULL pointer if you wish to ignore this parameter. When used, the PC clock time as seconds since 1970 of when the A/D conversion occurred will be returned. This value can be converted into the more common year/month/day hour:minute:second format with the SrSecTimeSplit function from SrHelper.c or with the standard C runtime function gmtime.

4.3 Scale data

C usage:

```
#include "Ser1ch.h"

        int Ser1chScaleData( long DataCounts,
                             double Slope,
                             double Offset,
                             double *DataScaled,
                             int *Error );
```

Once you have read a data sample in with GetData, you can use the function ScaleData to convert its raw A/D counts to other units such as volts or inches. ScaleData returns 1 for success and 0 for failure. It also takes an optional Error argument for returning more detailed information when a failure occurs. See Ser1ch.h for a list of the possible error codes, or use the ErrorMsg function to get the message string associated with the error number.

The first argument to ScaleData, DataCounts, is a 32 bit integer containing the A/D counts returned by GetData. The 24 bit A/D count is stored as a 32 bit integer with the top 8 bits always 0 ????

The second and third arguments, Slope and Offset, are 8 byte floating point doubles that are used to linearly convert from raw A/D counts to some other units such as volts. The scaled result is returned in the 8 byte floating point double parameter pointed to by DataScaled. Converting from A/D counts to converted scaled data is done using the slope and offset formula for a straight line:

$$\mathit{DataScaled} = \mathit{Slope} \cdot \mathit{DataCounts} + \mathit{Offset} \tag{4.1}$$

It is easy to compute the slope and offset from the information generated by the CAL programs. Use CAL to measure the A/D counts for two known values of A/D input. Often the input will be specified in terms of volts, but it can be in other units such as degrees or inches too. This results in two (DataCounts,DataScaled) pairs, $(C1, S1)$ and $(C2, S2)$. These two calibration points for the straight line equation (4.1) then imply that:

$$\begin{aligned} \mathit{Slope} &= (S2 - S1)/(C2 - C1) \\ \mathit{Offset} &= (S1 - \mathit{Slope} \cdot C1) \end{aligned}$$

The CAL programs do this computation and save the resulting slope and offset values in the generated .ini file DvmSetupCal.ini. Use these values as inputs to the ScaleData function. Note that systematic offsets, such as potentiometer offsets and op amp V_{io} errors, can be removed by specifing $S1 = 0$ when calibrating. Software offset correction is a powerful alternative to hardware trimming.

For the SER1CH-UA, the A/D counts always range from 0x00000000 to 0x00FFFFFF, (0 to 16,777,215 decimal), and the input voltages at which these count values occur are approximately 0 and 4.96 volts. Using these values, the slope in volts/count should always be approximately $4.96/16777215 = 2.96\text{e-}7$. The offset should always be approximately 0 because zero input volts maps approximately into 0 counts. Even if you don't have exact calibration numbers for a specific SER1CH-UA, you can still get reasonably good results for voltage calibration by using the approximate slope and offset numbers:

$$\begin{aligned} Slope &\approx \texttt{2.96e-7 volts/count} \\ Offset &\approx \texttt{0.0 volts} \end{aligned}$$

4.4 Get error message string

C usage:

```
#include "Ser1ch.h"

        char *Ser1chErrorMsg( int Error );
```

The ErrorMsg function takes an error number as input and returns a pointer to a null terminated string containing the corresponding message text.

Also see the C include file Ser1ch.h and source file Ser1ch.c for a listing of the error numbers and corresponding strings.

4.5 Close device

C usage:

```
#include "Ser1ch.h"

        int Ser1chClose( DEVHANDLE Ser1chHandle, int *Error );
```

The Close function closes the COM serial port. It should be the last library function called. Close returns 1 for success and 0 for failure.

The first argument to Close is the DEVHANDLE returned from the Open function. This is a 32 bit value representing a file handle to the open serial port. Under Windows it is equivalent to the Windows HANDLE type.

The second argument is a pointer to an integer that will be filled with an error code giving more detail than the simple (0,1) function return value. This argument is optional and will be ignored if you pass a NULL pointer. See Ser1ch.h for a list of the possible error codes. Or, use the ErrorMsg function to get the message string associated with the integer error number.

4.6 Code example

The following C program is a simple example of calling the SER1CH-UA function library. For simplicity it does not process the error code returns.

```
#include <stdio.h>
#include "Ser1ch.h"

#define SLOPE         2.96e-7F     // < approximate SER1CH-UA volts/count slope
#define OFFSET        0.0F         // < approximate SER1CH-UA offset in volts
#define FMT_STRING    "Data pt %02d is 0x%08lX counts or %lf volts at Time %lf\n"

int main( void ) {

    int i, Success, Error; long Data; double Scaled, Time;
    DEVHANDLE Ser1chHandle;

    // Open the SER1CH on COM1.
    Ser1chHandle = Ser1chOpen( 1, &Error );

    if ( Ser1chHandle == BAD_DEVHANDLE ) {
        printf( "Failed to open the SER1CH-UA on COM1 ...\n");
        return( 1 );
        }

    // Read and scale 50 data points.
    for ( i = 0 ; i < 50 ; i++ ) {

            Success = Ser1chGetData( Ser1chHandle, &Data, &Time, &Error );

            if ( Success == 1 ) {
                Ser1chScaleData( Data, SLOPE, OFFSET, &Scaled, NULL );
                printf( FMT_STRING, i, Data, Scaled, Time );
                }

            else
                printf("Data pt %02d failed because %s\n", i, Ser1chErrorMsg( Error ) );

            }

    // Close.
    Success = Ser1chClose( Ser1chHandle, &Error );
    return( 0 );
}
```

Figure 4.2: Sample C program calling Ser1ch library

Chapter 5

Sigma Delta A/D converters

Review that sigma delta A/D converters achieve their resolution by oversampling and averaging down and the boxcar averages result in a sinc response.

5.1 Sampling rate

Currently the sampling is set at 1Hz by a timer tick running on the PC.

The user has no control over the internal oversampling rate used in the LTC2400. It is nominally 7Hz, where this frequency is not crystal controlled and is set only by internal RC components inside the chip.

Furthermore, the LTC2400 has a relatively low oversampling rate, resulting in poorer resolution than other 24 bit A/D converters which have higher oversampling.

However, in return you get much lower power consumption. Compare the power usage and resolution with an A/D such as the LTC2440 series or ADS1255.

5.2 50/60Hz power line rejection

Because of their internal oversampling and digital filtering, sigma delta converters such as the LTC2400 used in the SER1CH-UA are capable of excellent power line noise rejection.

The internal sampling rate of the SER1CH-UA LTC2400 is automatically set to place the first notch of the sigma delta digital filter at 60Hz. International users may change the oversampling rate to place the first notch at 50Hz.

Review that the power line noise rejection is typically greater than 120 dB.

Chapter 6

Analog DC calibration

The physical quantity measured by the SER1CH-UA is voltage, with its A/D converter returning a count proportional to the input voltage. When the input voltage is low, a low count value is returned, and as the input voltage increases the count value increases.

The exact relationship between a particular input voltage and the A/D counts is referred to as the *DC calibration*. It is well approximated by a straight line with a *slope and offset*. Performing a calibration requires measuring the slope and offset so application software can convert counts into volts.

As shipped, the SER1CH-UA software is only approximately calibrated. Programs such as DVM have a typical slope and offset in their ini files. These values are reasonably good, but for highest accuracy, each SER1CH-UA must be calibrated on site by the user. The following sections cover the calculations involved with DC calibration. For an easy to use calibration program see the DVM CAL program.

To perform an absolute calibration requires either a precision voltage reference, or a precision voltmeter. Reference standards such as the Symmetric Research VREF-399 are suitable calibration tools. You can also use less stable voltage sources if you have an independent precision voltmeter such as an HP34401 to monitor the source with.

6.1 Full Scale Voltage Span and Counts

The SER1CH-UA has a 24 bit A/D converter with 2^{24} counts spread out evenly over the entire 0 to +5 volt input span of the system:

```
TOTAL 24 BIT A/D COUNTS = 2**24 = 16,777,216 (decimal)
```

Counts are returned by the GetData library function as 32 bit *integers*. For 0 input volts, zero counts will be returned, and as the VIN input voltage increases the count value will also increase. Counting upward from 0 volts to the maximum +5, there are 2^{24} counts. The SER1CH-UA is a single ended positive voltage system always returning postive counts.

Some of the count values for other input voltages are:

+ VIN (volts)	GND (volts)	Counts (hex)	Counts (decimal)
+5	0	0x00 FFFFFF	16,777,216
+5-e	0	0x00 FFFFFE	16,777,215
...			
+e	0	0x00 000001	0,000,001
0	0	0x00 000000	0,000,000
-e	0	0xFF FFFFFF	-0,000,001
...			
-4	0	0xFF C00000	-4,194,304
0	0	0x00 000000	00,000,000
0-e	0	0xFF FFFFFF	-00,000,001

Figure 6.1: A/D counts with single ended input

Of course, in actual practice resistor tolerances and op amp offsets will prevent the system from achieving a perfect zero counts at 0 volts, and likewise 2^{24} counts at full scale +5 volts. Nevertheless, to a reasonable approximation the above values are good working numbers.

If you need to measure voltages that are negative with respect to GND, please refer to the Scaling sensor voltages chapter.

6.2 Approximate counts per volt

With the total counts and the 16 volt span of the previous section in hand, the theoretical counts per volt for the USB4CH is:

```
Counts per Volt = (2**24)/16 =  1,048,576 counts / volt
```

or equivalently,

```
Counts per Millivolt =  1,049 counts / millivolt
 Counts per Microvolt =  1.0 count / microvolt
```

where the last two values are rounded. Of course the volts per count is just the inverse:

```
Volts per Count = 16/(2**24) =  1.0 microvolts / count
```

Note that because the A/D converters have noise floors greater than 24 bits, the resolution implied by these numbers may not be fully usable. For example, at a sampling rate of 100 Hz, the system has a noise free repeatable count value of 20 bits. There are four bits, or `(2**4) * 1.0 = 16` microvolts, of noise. You may prefer to work in 20 bit counts and 16 microvolts per count for your calculations at that sampling rate.

The input voltage span depends on the gain setting of the front end op amps. The above calculation assumes a gain of 1 on those amplifiers. By changing resistors on the board it is possible to run the amplifiers with gains of 1 to 100 with no increase in the noise floor. This is discussed in the Analog inputs chapter. The full scale input range will be smaller with added gain, but the counts per volt will be more sensitive.

We *do not recommend* using the ADS1255 PGA feature to increase the counts per volt. As with most sigma delta A/D converters claiming to have a PGA, the ADS1255 implements this function by changing the effective oversampling. When doing this the noise floor increases in direct proportion. This is in contrast to changing the gain of the USB4CH op amps, where the gain can be increased without corresponding noise floor increases.

6.3 Calibration slope and offset

For the general differential DC transfer function in the Analog inputs chapter,

```
A/D counts = slope * (V+ - V-) + offset
```

applied to a *theoretically* perfect USB4CH, the slope is the A/D counts per volt as in the previous section and the offset is zero. So the equation becomes:

```
A/D counts = 1,048,576 * (V+ - V-)
```

For most applications the calibration equation is actually used the other way around: given the A/D counts one wants to compute the corresponding voltage. The DVM program is one example. Given the A/D counts, we have:

```
(V+ - V-) = 9.53674e-007 * A/D counts
     9.53674e-007 = 1/1,048,576
```

and the slope and offset would be entered into the DVM ini file as:

```
 ChannelSlope x = 9.53674e-007   ; = ( 1/1,048,576 )
ChannelOffset x = 0
```

The ini files shipped with DVM for voltage display use these theoretically perfect values. Of course, physical components are never perfect and the true slope and offset will be slightly different from this ideal. For an exact calibration of any particular USB4CH channel, you should perform a physical calibration with the DVM Calibrate program. Note that besides calibration into volts, it is possible to calibrate A/D counts into other physical quantities such as temperature. The slope and offset can include the sensor response too.

The major contribution to offset error on USB4CH boards is the V_{io} input offset voltage of the front end op amps. No op amp is ideal, and the V_{io} parameter measures what input voltage may actually be required to zero the output. For the OPA2277 amps used on the USB4CH V_{io} is +/- 50 microvolts max. See the TI spec sheet for this V_{io} specification, as well as other details such as TC temperature variation. The following graph shows the offset spreads measured on 10 USB4CH boards for a total of 40 channels at 25 °C:

include graph here

Figure 6.2: Production input offset spreads

Chapter 7

Analog Resolution

This chapter covers the analog resolution of the SER1CH-UA. The term *resolution* has many meanings and can cause a great deal of debate. Superficially one could say the LTC2400 A/D converter used in the system is a 24 bit converter, and since it returns 24 bit integers, it has 24 bit resolution. Furthermore, if you know the input voltage span, you can compute the number of A/D *counts per volt* and have one measure of the resolution. See the Analog DC calibration chapter for a discussion of the *counts per volt* for the SER1CH-UA.

However, simply knowing the number of counts per volt does not give a complete picture of the system performance. The *noise floor and stability* of the conversions are equally important measures of the accuracy which will occur in real life applications.

The graphs and statistics given in the following sections should give an idea of the actual results possible with the SER1CH-UA.

7.1 Noise floor

The following graphs show the short term noise floor of the SER1CH-UA. The graphs present a variety of measurements.

`Work underway ...`

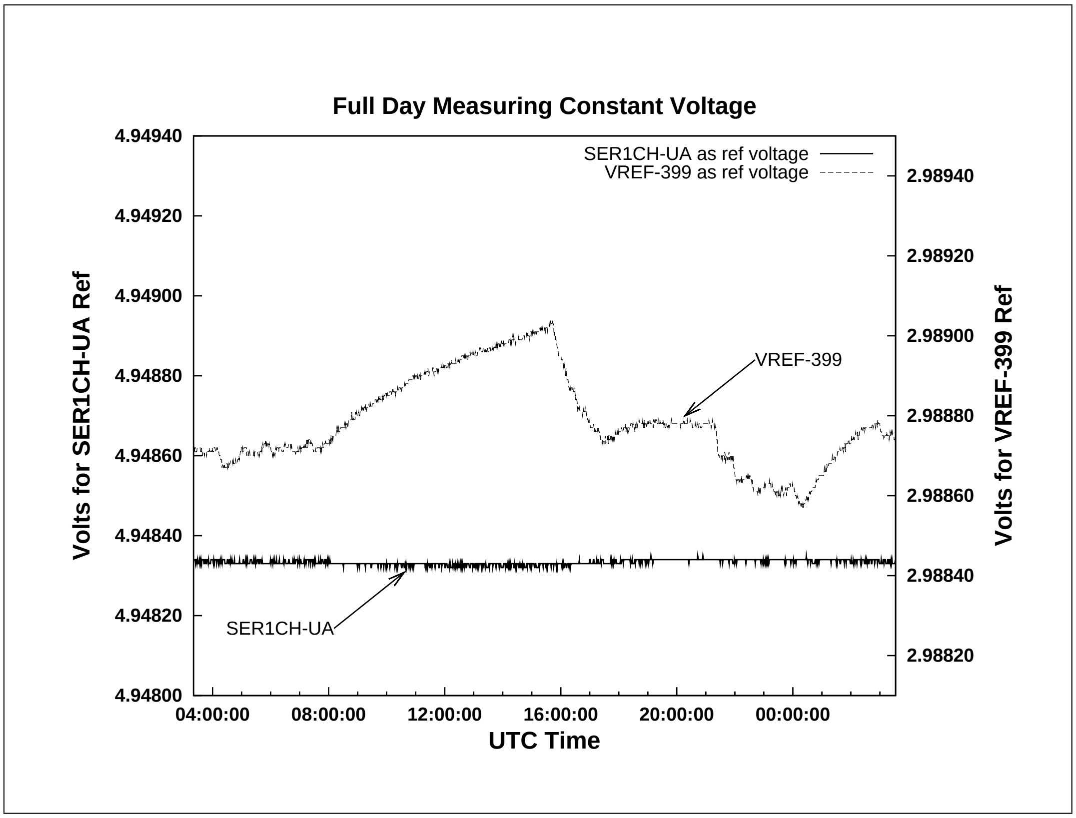


Figure 7.1: SER1CH-UA long term resolution plot

7.2 Thermal drift

When making measurments over long time periods, thermal drift can become a problem. The graphs in this section present a number of results for the thermal drift of the system.

`Work underway` ...

include graph here

Figure 7.2: Thermal drift plot

For effective ways to battle back against thermal drift, see the Ratiometric measurements chapter. The performance of ratiometric techniques is impressive and will greatly reduce thermal drift problems.

Chapter 8

Ratiometric measurements

When working with passive sensors, one of the best ways to use the SER1CH-UA is to make a *ratiometric measurement*. Such measurements are easy to set up and have the added benefit of excellent TC thermal performance. The classic ratiometric sensor is a potentiometer, and this section will use it as an example. For applications such as active sensors, where ratiometric techniques may not be possible, the Scaling sensor voltages chapter has interfacing methods which may be helpful.

The ratiometric concept is simple. All A/D converters use a reference voltage to set their full scale range. Voltages less than full scale are compared with the reference and a proportional number of counts returned. If measurements can be arranged so *the* A/D *reference is also used to excite the passive sensor*, then the sensor *and* A/D response will both scale in the same way. With this technique, measurements become insensitive to variations in the reference voltage or sensor excitation, yielding excellent results.

Let's use a few equations to see how ratiometric methods work. A/D converters accept an analog input voltage and produce a digital output count. The converter determines the output by comparing the input against a reference voltage. Denoting the A/D reference voltage by V_{ref} one might write:

$$AD_{counts} \;=\; (\; V_{in} \;/\; V_{ref}\;) \;\cdot\; AD_{FullScaleCounts} \tag{8.1}$$

where the $AD_{FullScaleCounts}$ is fixed by the architecture of the converter. In the case of a 24 bit converter, the full scale counts might be 0xFFFFFF, and an input voltage that is half of the reference would return 0x7FFFFF.

For most systems, the V_{ref} reference voltage is generated by a component separate from the A/D converter. In the case of the SER1CH-UA the reference is a 2.5 volt LM4040A bandgap device. This part has a typical 15 ppm/°C thermal variation, and so the reference voltage may vary by $(15 \cdot 10^{-6}) \cdot 2.5$ volts $= 37.5$ microvolts/°C. Equation (8.1) makes

it clear that changes in V_{ref} will affect the output counts as much as V_{in}, however we will see that with ratiometric methods the TC spec will hardly even matter. As a specific sensor example, let's consider a potentiometer. Many applications use potentiometers as position or angular sensors. The circuit for a potentiometer hooked up to the SER1CH-UA in ratiometric fashion is:

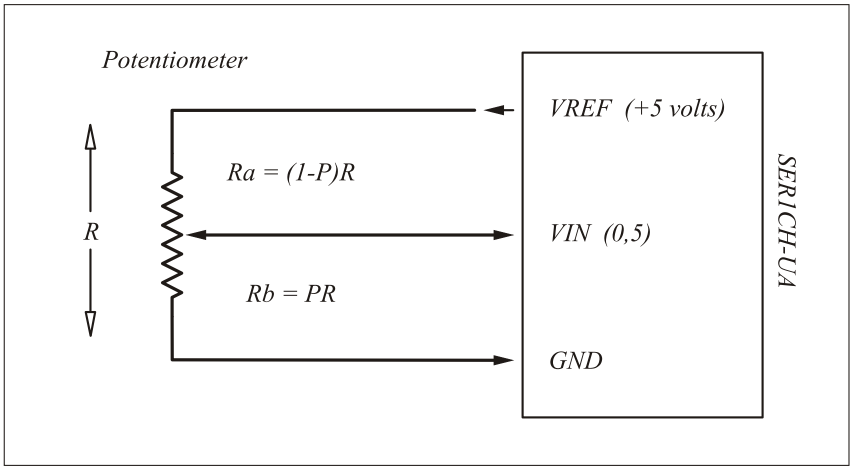


Figure 8.1: Potentiometer parameters

The three terminals of the potentiometer are simply connected directly to the SER1CH-UA banana jacks. With R as the total end to end potentiometer resistance, R_a and R_b as the resistances above and below the wiper, and the VREF jack providing the excitation, the potentiometer voltage is given by the resistor divider equation:

$$V_{in} = V_{wiper} = (R_b/R) \cdot V_{ref} = (PR/R) \cdot V_{ref} = P\,V_{ref} \tag{8.2}$$

where P denotes the physical wiper position, and ranges from 0 to 1, so that $R_b = PR$. Substituting this V_{in} into (8.1) results in:

$$\begin{aligned} AD_{counts} &= (V_{in} / V_{ref}) \cdot AD_{FullScaleCounts} \\ &= (P\,V_{ref} / V_{ref}) \cdot AD_{FullScaleCounts} \\ &= P \cdot AD_{FullScaleCounts} \end{aligned}$$

where the V_{ref} factor cancels and AD_{counts} is a function of only the potentiometer position *regardless of the value* V_{ref}! In fact, this is really a bridge or differential measurement. The A/D forms one side of the bridge, while the potentiometer forms the other side. As long as the voltage at the top of each leg of the bridge is the same, all that matters is the the *ratio* of the resistors on each side. Hence the term ratiometric measurement.

For the SER1CH-UA, a buffered copy of the A/D reference voltage is provided on the VREF banana jack. The VREF jack is capable of supplying 10ma, so keep the potentiometer end to end resistance greater than 500 ohms to avoid drawing too much current. A 10K pot is often ideal. The SER1CH-UA analog input has an input impedance of 10M ohms so the potentiometer wiper will not be significantly loaded by VIN. For a hands on demonstration using a 10 turn potentiometer in ratiometric fashion see the Ratiometric potentiometer in the Examples and Experiments chapter.

Just how good are ratiometric techniques? The following graph compares a potentiometer excited by the VREF jack with the same potentiometer excited by an external precision reference, the SR VREF-399. Even though the external reference has near perfect stability and precision, thermal variation in the SER1CH-UA LM4040A cause the SER1CH-UA response to appear to drift. By simply using the VREF jack for excitation, the potentiometer drifts in exactly the same way as the A/D giving near perfect results. If external excitation such as a battery had been used instead of the VREF-399, the comparison would have been only yet more dramatic.

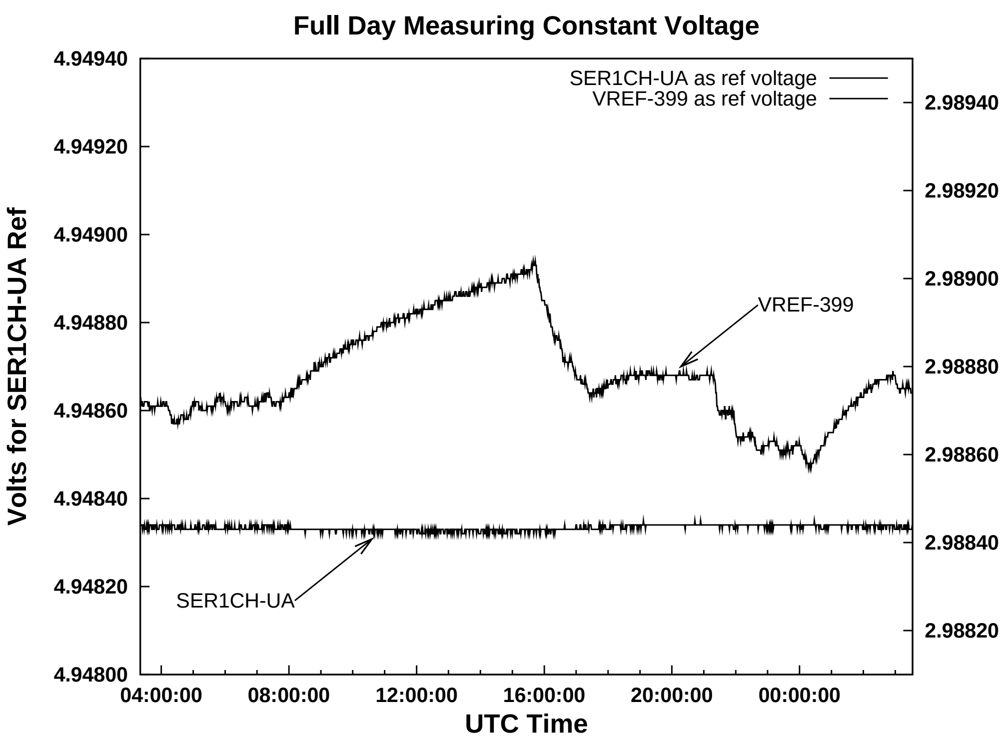


Figure 8.2: SER1CH-UA ratiometric comparison

A wide range of three terminal passive sensors have outputs proportional to the product of their settings and excitation. Ratiometric techniques will work equally well for all of them. However, if you have only a two terminal sensor, don't despair. You can still gain the benefits of ratiometric measurement.

Work underway ...

Chapter 9

Scaling sensor voltages

The full scale input range of the SER1CH-UA is 0 to +5 volts. If you have an active sensor with a different range, even including negative voltages, you can use scaling and biasing to map its output to be compatible with the SER1CH-UA (0,5) range.

Scaling and biasing is usually not required for passive sensors. Passive sensors such as potentiometers typically have their full scale output range set by their excitation voltage. If the excitation is supplied by the SER1CH-UA VREF, a full scale sensor range of (0,5) results naturally with no scaling or biasing required. Such techniques are covered in the Ratiometric measurements chapter, and also have excellent TC thermal performance.

Active sensors on the other hand usually include op amps in their design. They require an independent power supply and commonly have a output range of (-5,+5) or (-10,+10) volts. When working with these types of sensors, it is desirable to scale and bias their full range into the SER1CH-UA (0,5) so none of the 24 bit A/D span is lost.

A few of the more popular circuits for mapping active sensor ranges are reviewed in this chapter. In many cases, precision low noise mapping can be done with a few resistors, while for applications requiring gain an op amp may be required. For additional information you may also find the following useful:

- the Examples and Experiments chapter for a hands on (-10,+10) demo
- the SR paper, *Scaling and Biasing Analog Signals* for theory

SR papers and app notes can be found on the web at: www.symres.com
The following sections give a quick review of the techniques

9.1 Resistive scaling and biasing

Active sensors usually have output ranges reflecting the op amps and power supplies they use. The most common ranges are (-5,+5) and (-10,+10) volts, and this section reviews resistive circuits for mapping these ranges into the SER1CH-UA (0,5) volts. Besides being simple, these circuits introduce very little noise to the signal. Furthermore, active sensor outputs can usually drive the moderate input impedance of these circuits to full accuracy, while the SER1CH-UA 10M ohm input presents no load to them either.

The circuit for mapping (-5,+5) volts into (0,5) is:

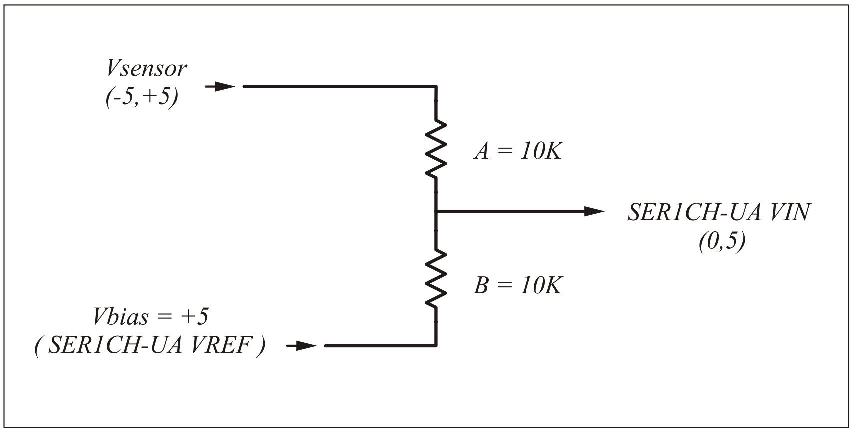


Figure 9.1: Two resistor scaling and biasing (-5,+5) into (0,5)

This design uses *two resistors* and the SER1CH-UA VREF as its bias source. For easy construction, use 1/4 watt metal film resistors with leads. Carbon film resistors are not recommended because they have poor noise and TC characteristics, with only a small savings in cost. For vendors carrying 1% metal film resistors, see the Extra supplies chapter. See the SR paper *Scaling and Biasing Analog Signals* for the theory behind this circuit.

When using this circuit, note that if the V_{sensor} input is allowed to float, it will drift to +5 volts and *not* ground. If you measure the floating input with a Fluke or other voltmeter it will read +5 volts. The SER1CH-UA itself will also return +5 volts if the V_{sensor} input is allowed to float. To work correctly, the input must be driven by a low impedance source such as an active sensor output. If you want to temporarily hardwire the input low, connect it to ground with a wire.

The next circuit is suitable for mapping (-10,+10) volts into (0,5). This design uses *three resistors* and the SER1CH-UA VREF as its bias source. As with the previous circuit, use 1/4 watt metal film resistors for best performance. If you don't have a 5K ohm resistor on hand, build one from two 10K resistors in parallel. For a hands on demo of this circuit, see the Examples and Experiments chapter.

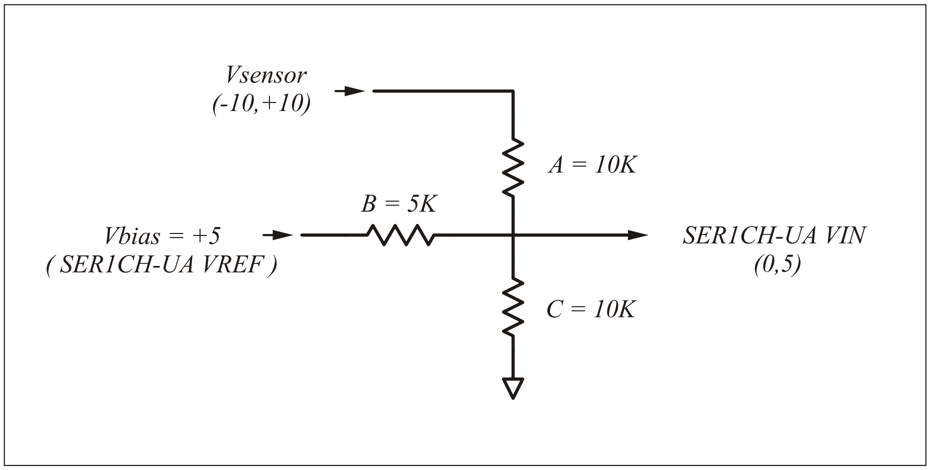


Figure 9.2: Three resistor scaling and biasing (-10,+10) into (0,5)

As with the two resistor circuit, if the input of the three resistor circuit is allowed to float, its output will drift to a non zero voltage. With the values above, it will drift to 3.3 volts. Connect the V_{sensor} input to ground if you wish to temporarily drive the input low for a test. For other input ranges, the this circuit can be modified with different resistor values and still use the SER1CH-UA VREF as the bias source. The following table lists some possible values:

	Bipolar input	ΔV_{in}	V_{out}	A(Kohm)	B(Kohm)	C(Kohm)
	(+/-) 06.0	12.0	(0,5)	10.000	8.333	50.000
	(+/-) 07.0	14.0	(0,5)	10.000	7.143	25.000
	(+/-) 08.0	16.0	(0,5)	10.000	6.250	16.667
	(+/-) 09.0	18.0	(0,5)	10.000	5.556	12.500
⋆	(+/-) 10.0	20.0	(0,5)	10.000	5.000	10.000
	(+/-) 11.0	22.0	(0,5)	10.000	4.545	8.333
	(+/-) 12.0	24.0	(0,5)	10.000	4.167	7.143
	(+/-) 14.0	28.0	(0,5)	10.000	3.571	5.556
	(+/-) 16.0	32.0	(0,5)	10.000	3.125	4.545
	(+/-) 18.0	36.0	(0,5)	10.000	2.778	3.846
	(+/-) 20.0	40.0	(0,5)	10.000	2.500	3.333

Figure 9.3: Three resistor values for various input ranges with V_{bias} = VREF

9.2 Op Amp scaling and biasing

Adding op amps to the resistive circuits in the previous section provides further possibilities for scaling and biasing. Besides increasing the input impedance of a resistive divider, op amps can perform signal conditioning such as adding gain or filtering. This section reviews two possibilities.

The following circuit uses a unity gain buffer to increase the input impedance of its 10K/3.3K scaling and biasing pair into the Mohm range. The 3.3v bias required for this circuit is derived from the 10K/20K divider on VREF which is then op amp buffered to be stable and constant.

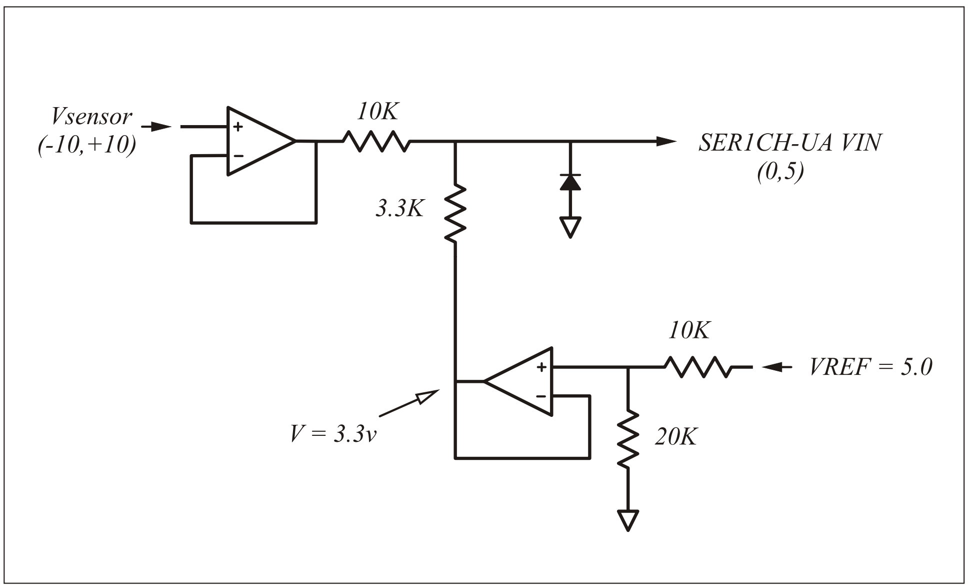


Figure 9.4: Op amp unity gain buffer with scaling

Note the input amplifier above will need a split power supply in order for its non inverting input to respond to negative signals. Typically a split supply like +/-12 will be required. By comparison, the purely resistive circuits in the previous section require only VREF from the SER1CH-UA. We assume op amp users are familiar with their power requirements.

You may also wish to include a small diode above to prevent accidental negative excursions from being presented to the SER1CH-UA (0,5) input. This might happen if the (-10,+10) input went more negative than -10 volts. No damage will occur to the SER1CH-UA with negative inputs, but preventing it from happening is a good precaution.

Inexpensive bipolar op amps such as the LM358 (dual) or LM324 (quad) can offer surprisingly good performance in such circuits. With their multiple op amps per IC package, such

devices make it easy to build circuits requiring multiple amps and buffers. When using generic parts, remove amplifier input offset errors in software.

The next circuit adds gain to the input signal. After amplifying by 10, the signal is scaled and biased into the SER1CH-UA (0,5) range with the 10K resistor pair. When building a design like this, it is ideal to place the gain amplifier out near the sensor. Low voltage signals like the +/-500mV input are much more sensitive to noise pickup than high voltage levels. Any long cable could then be placed between the output of the gain amplifier and the 10K divider pair. Check to make sure the cable capacitance has not caused instability and amplifier oscillations.

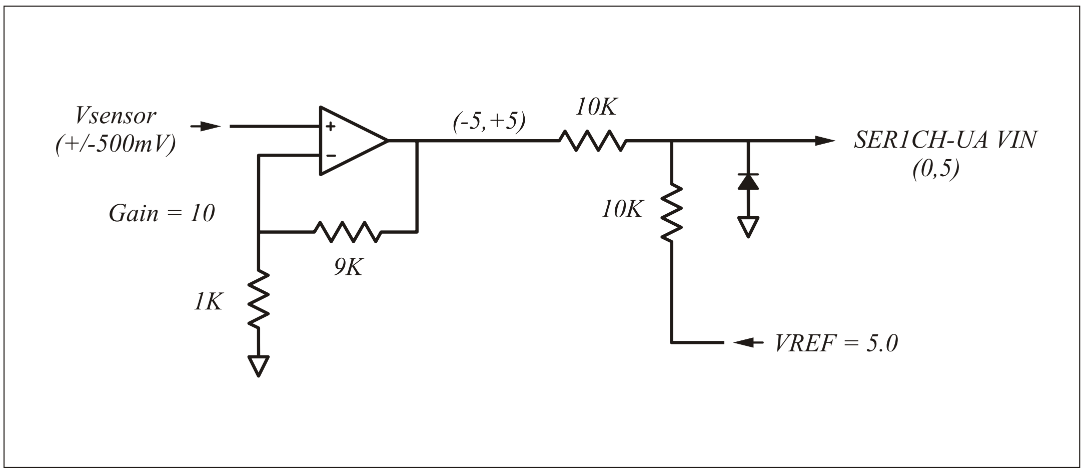


Figure 9.5: Op amp buffer with gain of 10

With the small input range of this circuit, it is easy for a signal more negative than -500mV to get hooked up to the input by accident. As before, a small diode may be added to protect against negative voltages at the SER1CH-UA VIN input.

For a single ended circuit such as this, do not allow ground currents from other devices to flow on the ground wire of the cable connecting the op amp to the SER1CH-UA GND jack. Excessive common mode currents, such as those from motors, will bounce the ground connection and be apparent in the SER1CH-UA measurements.

Chapter 10

Single ended grounding practices

The SER1CH-UA has a single ended input. Excessive currents flowing on the black GND banana pin will affect *absolute* measurement accuracy.

`Work underway` ...

Chapter 11

Batteries and minimizing power

With its small current consumption, the SER1CH-UA is a good match for many low power bit banging applications. This chapter reviews the steps required for achieving the lowest power possible. The steps are easy, but important to be aware of for success.

The chapter sections review how to measure the SER1CH-UA current consumption, then a check list of power minimizing steps, and conclude with an example of using battery power.

11.1 Measuring current consumption

The physical current consumed by the SER1CH-UA can be measured in a various ways. If the unit is out of its enclosure, one way is to measure the voltage drop across the 5.1 ohm antisurge resistor R900 in the power supply area of the board. Then use Ohm's law to compute the current.

If the unit is in its enclosure, you have two options. One is to include an external series resistor in the power supply line. Any resistor with a few ohms to a hundred ohms resistance will suffice. The voltage drop then implies the current. Alternatively, you can use an ammeter in series with the power supply and read the current directly. It will require an accurate ammeter with better than 1 milliamp accuracy.

Once you have measured the current consumption, you'll of course want to compare it against the quoted specs. The table below computes the theoretical maximum base power requirement. Not all these individual current components are consumed at the same time and usually the typical current consumption will be approximately 600 microamps as quoted in the specification table.

```
SER1CH-UA MAXIMUM BASE POWER CONSUMPTION ...

  PART        DESCRIPTION                     CURRENT CONSUMPTION IN milliamps

  R112        47K @ 5v                                                 0.10638
  R115        47K @ 5v                                                 0.10638
  R122        1M @ 5v                                                  0.00500
  U110        74HC14 quiesent                                          0.04000
  U200        LTC2400 A/D converter, while running                     0.20000
  R211        100K @ 5v                                                0.05000
  U210        TLC27L2 quiesent                                         0.03400
  U910        TLC27L4 quiesent                                         0.06800
  R921        LM4040 with 24K source resistor, 2.5v / 24K              0.10417
  R922        100K @ 2.5v                                              0.02500
  R923        100K @ 2.5v                                              0.02500

        Total base current consumption (in milliamps) = 0.76393
```

Figure 11.1: Maximum base power consumption

11.2 Minimizing power

If you are consuming more current than the amount listed in the table in Figure 11.1, there are four possible offenders:

- The green power LED is on, consuming 10 milliamps !
- A low value resistance is connected between VREF and GND
- Custom software is not handling the RS232 port correctly
- The power supply is greater than 18 volts

Disconnecting the green power LED can be done by removing jumper J910 on the board. It may be hard to believe a simple green LED can consume over 10 times more current than the A/D circuit itself, but it is true. Removing the LED jumper will save that current. Having a visible power indicator is handy in the lab, but takes its toll when running from batteries.

After disabling the green power LED, it is also easy to forget that resistive loads connected between the VREF banana jack and GND will consume additional power. For example, if a 1K ohm potentiometer is connected between VREF and GND, that alone will consume 5 milliamps. And, that 5 milliamps will have to be supplied by the SER1CH-UA power supply. A 10K potentiometer would a give a better tradeoff between avoiding noise and minimizing power consumption.

The third item, handling the RS232 serial port correctly, is a concern only if you are writing your own custom software. The problem is with RS232 inputs on the PC end of the DB9 cable and the impedance they present, typically 5K ohms. If such an input is driven at +5 volts by the SER1CH-UA then this will consume 1 milliamp, which ultimately must provided by the power supply.

The way to battle against the third item is to note the SER1CH-UA has only one input to the PC RS232 port, the CTS signal. Don't idle this signal high or you will sink unnecessary current on the order of 1 to 2 milliamps. An easy way to avoid touble is to assert the LTC2400 chip select signal (RS232 RTS) only when needed. When this signal is deasserted, then the CTS input will automatically idle low and not burn unnecessary power. Application programs like DVM supplied with the SER1CH-UA do this automatically.

The last item, using a power supply greater than 18 volts, is a serious error. Circuity on the SER1CH-UA would be damaged by power greater than 18 volts and is protected by a TVS device. When the external power supply exceeds 18 volts, the TVS turns on and clamps the voltage to safe levels. Normally, the TVS is there to protect against power supply spikes. However, if the power supply voltage is simply too high, the TVS will equally well turn on and present a heavy load to your external supply. Check your power supply equipment beforehand and *don't exceed 18 volts.*

11.3 Batteries

Once you have minimized the power consumption of the system, you may be interested in powering the SER1CH-UA from batteries. 9 volt batteries are attractive temporary power supply for this system, running over 100 hours. For longer term power, lead acid 12 volt batteries are useful.

`Work underway` ...

Chapter 12

Specifications

The table on the following page lists the leading SER1CH-UA operating specifications. Many of the values are discussed in more detail in their respective chapters. The table here lists the primary analog components used on the board. Copies of the manufacturer specification sheets are also included in the directory /Docs/ChipSpecs.

A/D converter	=	LTC2400	(Linear Technology)
A/D voltage reference	=	LM4040A	(National Semiconductor)
Front end op amp	=	TLC27L2	(Texas Instruments)

12.1 Specifications table

SER1CH-UA Specs					
Parameter	**Comment**	**Min**	**Typ**	**Max**	**Units**
Analog input:					
VIN input voltage range		0		5.0	Volts
VIN input impedance			10M		Ω
Resolution			24		bits
Noise Floor (1)			10		μV
Reference:					
VREF voltage			4.8		V
VREF current				10	mA
VREF capacitive load				10	μF
Power supply:					
Supply Voltage		8	9	16	Vdc
Supply Current (2)	converting		600		μA
Supply Current (3)	sleeping		200		μA
General:					
RS232 cable length (4)			6	100	feet
Operating Temperature		0		70	°C
Dimensions			2.13 x 3		inches

Figure 12.1: SER1CH-UA specifications table

(1) Peak to peak noise floor.
(2) Continuous current when performing conversions, with LED off and no VREF load.
(3) Sleep mode occurs when the LTC2400 CS pin is held high.
(4) Longer cables may be possible, 100 ft is the tested limit.

12.2 Noise floor

`Work underway` ...

noise floor plot

Figure 12.2: SER1CH-UA noise floor

12.3 Thermal response

`Work underway` ...

thermal response plot

Figure 12.3: SER1CH-UA thermal response

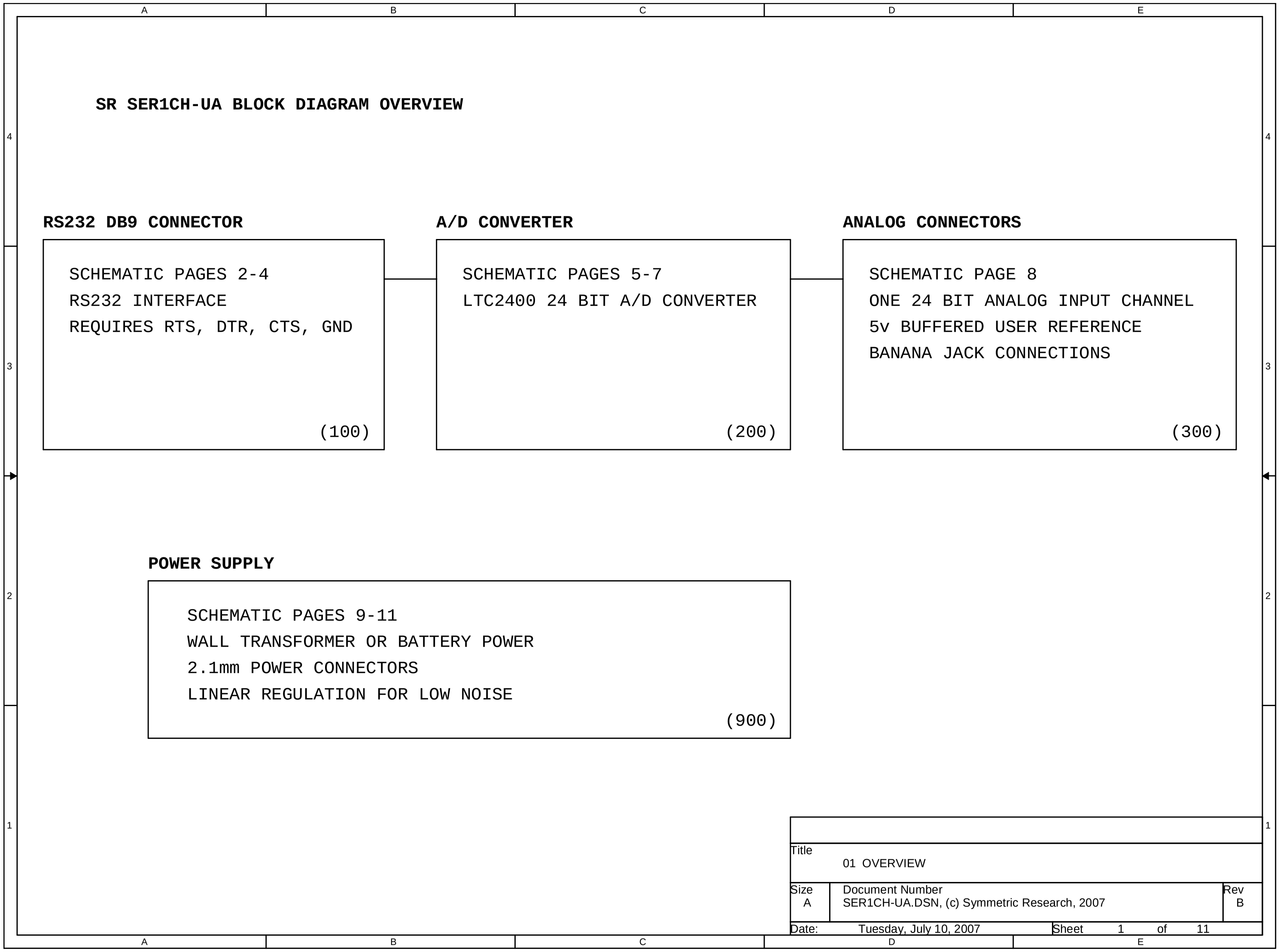
Chapter 13

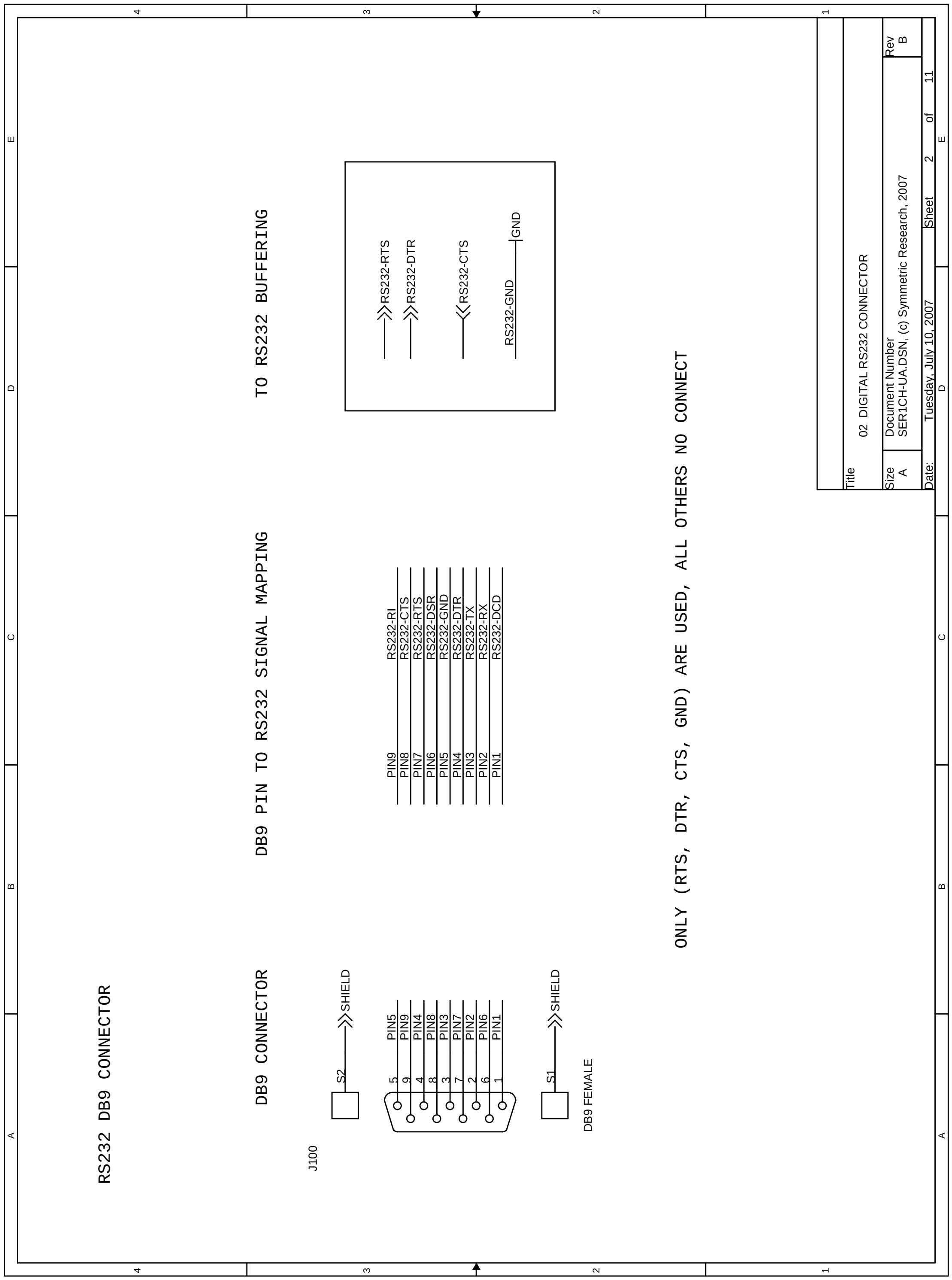
Circuit diagrams

FREE WEB VERSION - PARTIAL CIRCUIT DIAGRAMS

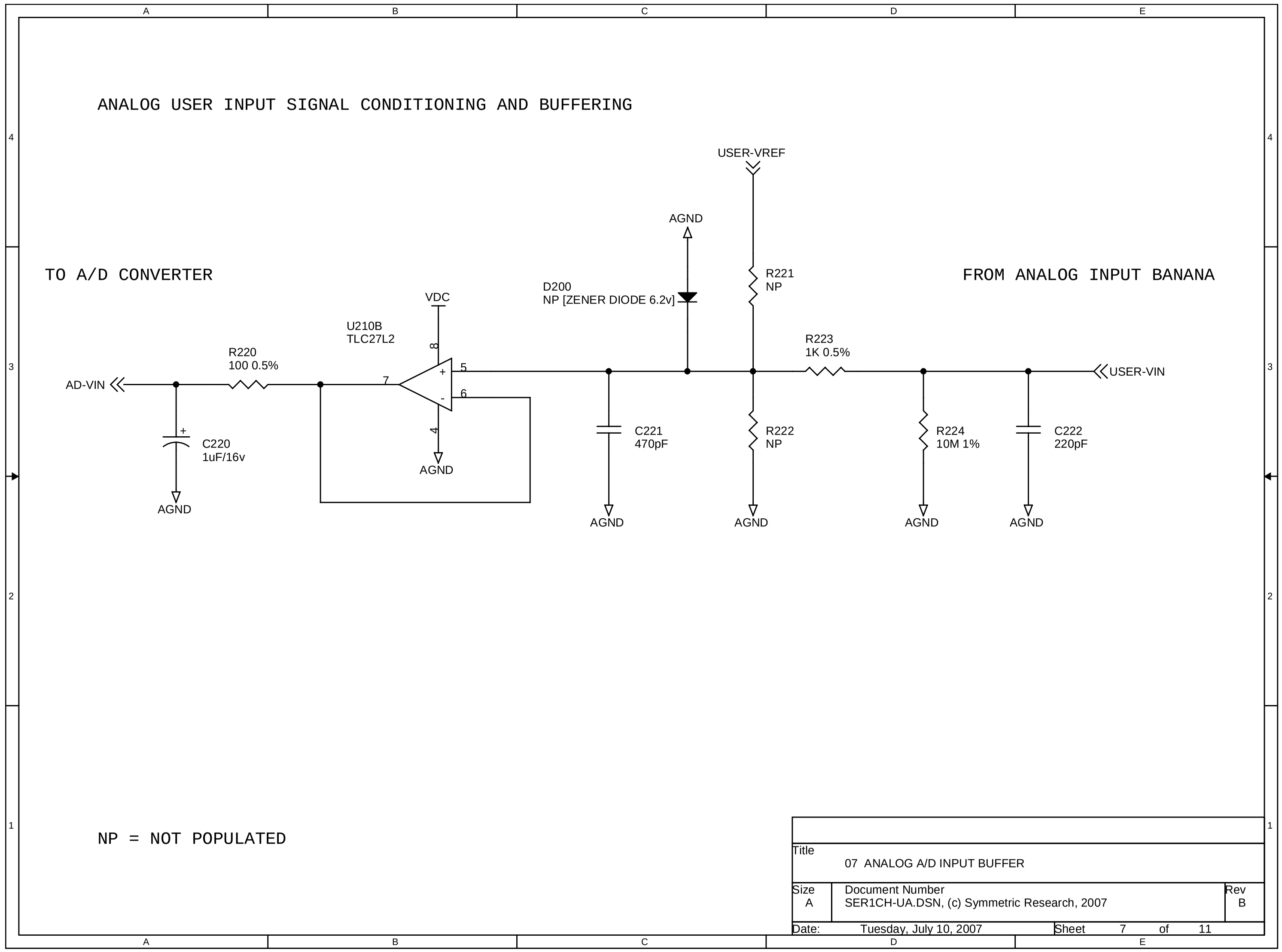
This free web copy of the User Manual includes only partial diagrams with the circuit Overview and the VIN analog input amplifier. Complete circuit diagrams are provided only with purchase of the product. Install the CDROM software included in the product shipment box for the full User Manual and complete diagrams. Customers who need an update or have lost their original CDROM may obtain copies of the full User Manual by emailing SR at info@symres.com.

Use the Adobe Acrobat reader View/Rotate View/Clockwise command to present the diagrams horizontally on the screen.

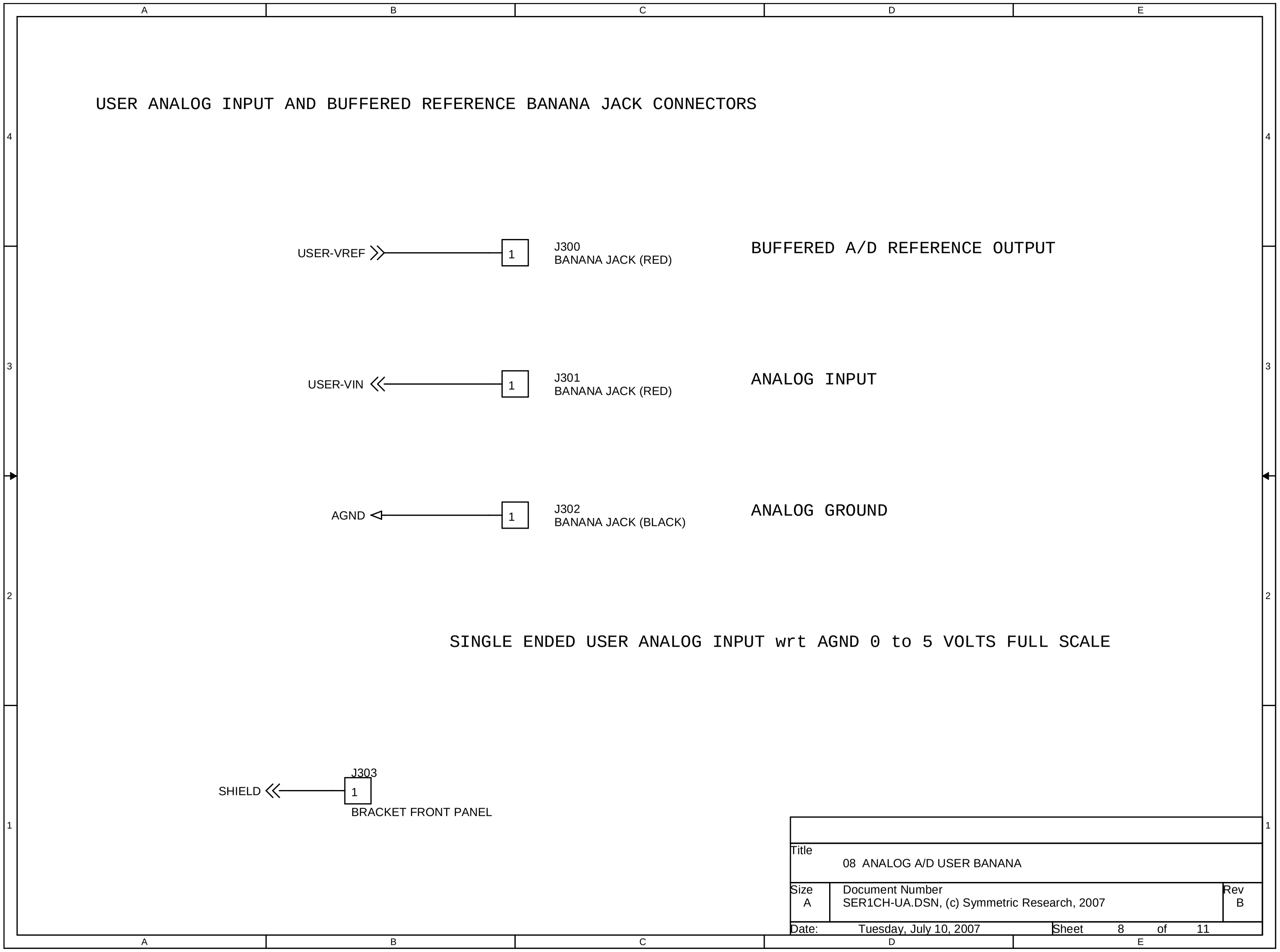

SR SER1CH-UA BLOCK DIAGRAM OVERVIEW
RS232 DB9 CONNECTOR
SCHEMATIC PAGES 2-4
RS232 INTERFACE
REQUIRES RTS, DTR, CTS, GND
(100)
A/D CONVERTER
SCHEMATIC PAGES 5-7
LTC2400 24 BIT A/D CONVERTER
(200)
ANALOG CONNECTORS
SCHEMATIC PAGE 8
ONE 24 BIT ANALOG INPUT CHANNEL
5v BUFFERED USER REFERENCE
BANANA JACK CONNECTIONS
(300)
POWER SUPPLY
SCHEMATIC PAGES 9-11
WALL TRANSFORMER OR BATTERY POWER
2.1mm POWER CONNECTORS
LINEAR REGULATION FOR LOW NOISE
(900)
Title
01 OVERVIEW
Size
A
Document Number
SER1CH-UA.DSN, (c) Symmetric Research, 2007
Rev
B
Date: Tuesday, July 10, 2007
Sheet 1 of 11



RS232 DB9 CONNECTOR
DB9 CONNECTOR
DB9 PIN TO RS232 SIGNAL MAPPING
TO RS232 BUFFERING
J100
S2
SHIELD
S1
SHIELD
DB9 FEMALE
5 9 4 8 3 7 2 6 1
PIN5 PIN9 PIN4 PIN8 PIN3 PIN7 PIN2 PIN6 PIN1
PIN9 RS232-RI
PIN8 RS232-CTS
PIN7 RS232-RTS
PIN6 RS232-DSR
PIN5 RS232-GND
PIN4 RS232-DTR
PIN3 RS232-TX
PIN2 RS232-RX
PIN1 RS232-DCD
RS232-RTS
RS232-DTR
RS232-CTS
RS232-GND
GND
ONLY (RTS, DTR, CTS, GND) ARE USED, ALL OTHERS NO CONNECT
Title
02 DIGITAL RS232 CONNECTOR
Size A
Document Number
SER1CH-UA.DSN, (c) Symmetric Research, 2007
Rev B
Date: Tuesday, July 10, 2007
Sheet 2 of 11



ANALOG USER INPUT SIGNAL CONDITIONING AND BUFFERING
TO A/D CONVERTER
FROM ANALOG INPUT BANANA
USER-VREF
AGND
D200
NP [ZENER DIODE 6.2v]
R221
NP
VDC
U210B
TLC27L2
R223
1K 0.5%
R220
100 0.5%
AD-VIN
USER-VIN
C220
1uF/16v
C221
470pF
R222
NP
R224
10M 1%
C222
220pF
AGND
NP = NOT POPULATED
Title
07 ANALOG A/D INPUT BUFFER
Size
A
Document Number
SER1CH-UA.DSN, (c) Symmetric Research, 2007
Rev
B
Date: Tuesday, July 10, 2007
Sheet 7 of 11


USER ANALOG INPUT AND BUFFERED REFERENCE BANANA JACK CONNECTORS
USER-VREF
1
J300
BANANA JACK (RED)
BUFFERED A/D REFERENCE OUTPUT
USER-VIN
1
J301
BANANA JACK (RED)
ANALOG INPUT
AGND
1
J302
BANANA JACK (BLACK)
ANALOG GROUND
SINGLE ENDED USER ANALOG INPUT wrt AGND 0 to 5 VOLTS FULL SCALE
SHIELD
J303
1
BRACKET FRONT PANEL
Title
08 ANALOG A/D USER BANANA
Size
A
Document Number
SER1CH-UA.DSN, (c) Symmetric Research, 2007
Rev
B
Date: Tuesday, July 10, 2007
Sheet 8 of 11

Chapter 14

Examples and Experiments

The following are a few hands on demonstrations using the SER1CH-UA. Several of these examples show how to implement topics covered in previous chapters. These are starting points and should be modified as necessary for the work at hand.

14.1 Basic voltage measurements with probes

Measuring a voltage with the SER1CH-UA is similar to using other voltmeters, with the voltage source being connected between the red VIN and black GND banana jacks. Figure 14.1 shows a pair of AA batteries in series, and the alligator test leads supplied with the system used to measure their voltage.

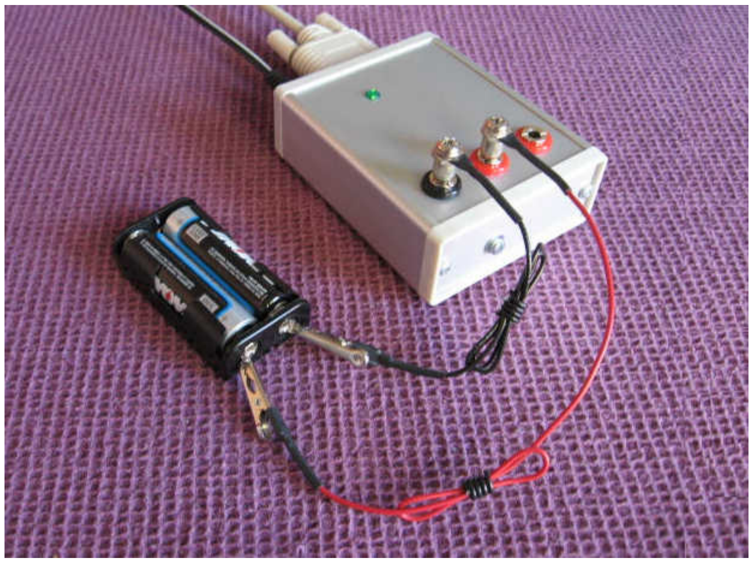
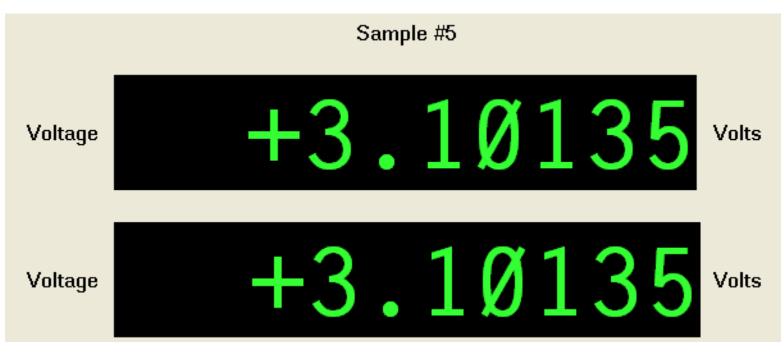


Figure 14.1: Two lead voltage measurement of a battery

*** WHAT HAPPENS IF THE BATTERY IS HOOKED UP IN REVERSE ??????

Since two AA cells in series is approximately 3 volts, if you use the DVM program with the startup file DvmVoltage.ini you should see the following on your computer screen:



In this particular DVM display, both readouts have been calibrated in volts. For many

applications it is useful to calibrate the second DVM readout into other more physical units proportional to the voltage, such as potentiometer position, temperature, etc. It is convenient to have two readouts so you can monitor the raw sensor voltage while also displaying the physically sensed quantity. See the *Software* chapter of this User Manual and the CAL program for more details.

Besides using the alligator leads supplied with the system, you can also use standard red/black banana plug test leads. In Figure 14.2, a pair of Pomona test leads are shown connected to the SER1CH-UA banana jacks. If you need a pair of heavy gauge test leads, they may be ordered as an accessory for the basic system.

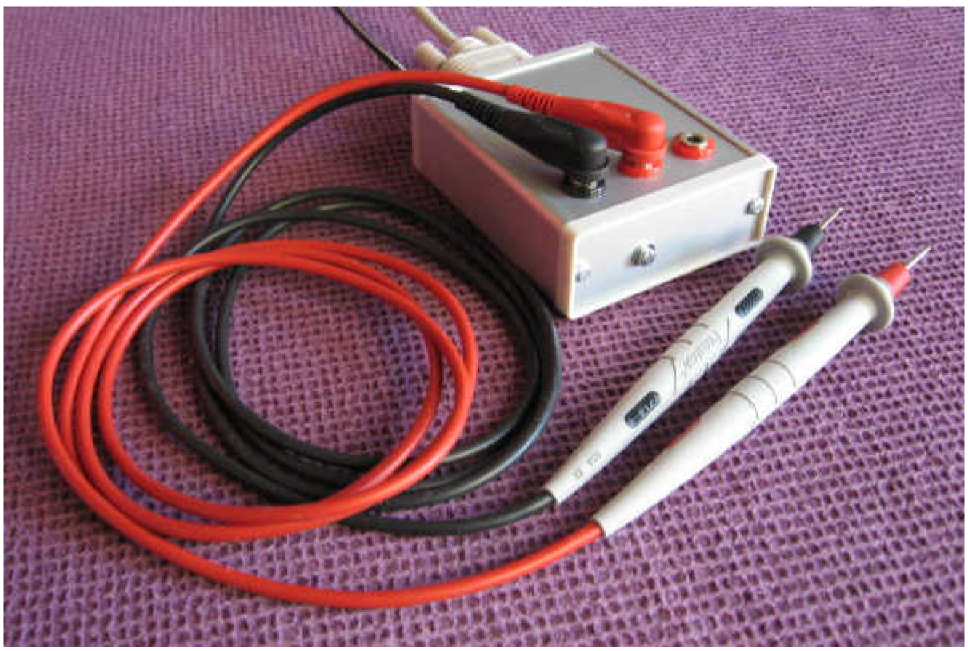


Figure 14.2: Pomona test leads for voltage measurements

When making two wire voltage measurements as in Figures 14.1 and **??**, be aware the black GND banana jack is ultimately connected to the power ground and enclosure of the PC via the DB9 RS232 serial port connector. The analog inputs *are not floating* as they are with a hand held voltmeter. Also be aware current flowing in the ground system can cause noise in your measurements. Use a star layout for ground and ideally keep your sensor at one end of the star without system ground currents passing though its circuit.

Another difference with typical hand held voltmeters is the voltage between the VIN and GND jacks should be in the range of (0,5) volts. The system will tolerate moderate voltages outside of this range, but *do not attempt to measure 110 vac from the wall socket with this device.* Doing so will void the warranty. If you need to measure voltages outside the (0,5)

range, please use the techniques in the *Scaling active sensor voltages* chapter in this User Manual, or the (-10,+10) section further on in these examples.

Simply being able to measure and record voltages provides many possibilities for interesting applications. As an example, Figure 14.3 shows using a solar cell as a light sensor. The voltage generated by the solar cell is a measure of the amount of light shining on it. The cell in Figure 14.3 has a voltage ranging from 0 volts at total darkness to approximately 3 volts at full brightness.

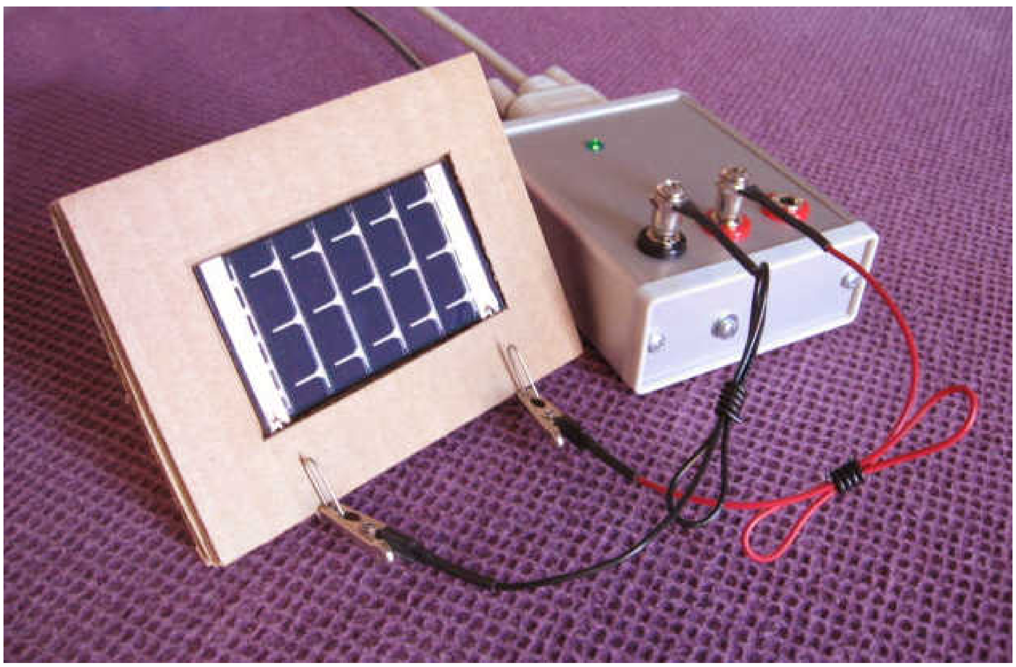


Figure 14.3: Using a solar cell as a light level meter

Not only can you measure the solar cell voltage with DVM, you can also calibrate the second DVM readout to display the value in light level units. Having a second readout calibrated into physical units makes it easy to determine the current condition of a sensor.

Besides its real time GUI readout display, DVM also saves its data values to a disk file. This makes it easy to review results after a long data run. The next chapter section shows how to take a DVM output file and plot the results with GnuPlot on the computer screen or printer.

14.2 Plotting results with GnuPlot

After acquiring data with the SER1CH-UA, you may want to plot the values. GnuPlot is a useful public domain program for displaying results on the computer screen or printer in a variety of formats. Copies can be downloaded for free from the web at:

www.sourceforge.net

or found by searching the web on the keywords GnuPlot. PDF documentation is included with GnuPlot when it is unpacked. Programs such as Xcel and MatLab may also provide useful plotting tools for users already having those programs.

The techniques for plotting results with GnuPlot or similar programs all follow the same pattern. First, run the SER1CH-UA DVM program to acquire values and save the results to an output disk file. For this example we assume data from the solar cell in the previous section has been saved in the file DvmOutputSolar.asc. The DVM output files are in ASCII format with the data in columns which can be imported into plotting programs. The .asc output files may also be reviewed in text editors such as Notepad. The following is a portion of the DVM .asc output data file that might result:

```
Data:

     Sample       Volts    OneToTen    Time (Sec)        Time (YMD HMS)
          1        +0.7       +1.42  1202171952.468  2008/02/05 00:39:12.468
          2        +0.7       +1.43  1202171953.629  2008/02/05 00:39:13.629
          3        +0.7       +1.43  1202171954.791  2008/02/05 00:39:14.791
          4        +0.7       +1.45  1202171955.953  2008/02/05 00:39:15.953
          5        +0.7       +1.49  1202171957.114  2008/02/05 00:39:17.114
          6        +1.0       +2.01  1202171958.276  2008/02/05 00:39:18.276
          7        +0.9       +1.90  1202171959.438  2008/02/05 00:39:19.438
          8        +1.0       +1.99  1202171960.599  2008/02/05 00:39:20.599
          9        +1.2       +2.34  1202171961.761  2008/02/05 00:39:21.761
```

Figure 14.4: DVM output file fragment from DvmOutputSolar.asc

To produce an output file with these data columns, DVM was run with the .ini startup parameters shown in Figure 14.5. Besides the general output format, this .ini file also specified the second display should be formatted in light level units of 1 to 10. You may wish to calibrate into other light level units as appropriate.

Once the DvmOutputSolar.asc file has been acquired, start GnuPlot and issue the commands in Figure 14.6 at its prompt.

```
; General ini parameters:

OutputFileName         = "DvmOutputSolar.asc"
OutputFileComment      = "Measuring solar panel response"
OutputFileShowHeader   = ON
OutputFileShowIndex    = ON
OutputFileShowTimeSec  = ON
OutputFileShowTimeYmd  = ON
RunMode                = CONTINUOUS

; Display 1 format and calibration parameters:

DisplayTitle  1 = "Light Level"
DisplayUnits  1 = "OneToTen"
DisplayPlaces 1 = 6
DisplayDigits 1 = 2
DisplaySlope  1 = 6.02121e-007
DisplayOffset 1 = -0.00147941
```

Figure 14.5: DVM startup file fragment from DvmSetupSolar.ini

You can also save the commands in Figure 14.6 to a file and then run them in GnuPlot with the load command. The file Solar.gp in the examples software directory has the complete set of commands required to produce the following graph. The core GnuPlot command is plot. With that single command you can display simple plots. Additional commands should be used for features like graph titles. Refer to the GnuPlot documentation for more information.

```
# SET FILE FORMAT PARAMETERS:

DataFile  = "DvmOutputSolar.asc"
ColSample  = 1
ColVolts   = 2
ColLight   = 3
ColSeconds = 4
ColTime    = 5

# SET AXIS DATA LIKE TIC MARK STYLE, FORMAT, LABEL AND RANGE:

set xtics nomirror  font "Helvetica Bold,14"
set ytics nomirror  font "Helvetica Bold,14"
set xlabel "Sample" font "Helvetica Bold,18"
set ylabel "Volts"  font "Helvetica Bold,18"
set xrange [0:120]  # About 2 minutes of data
set yrange [0:5]    # Solar panel outputs ~3.3v in strong sunlight

# PLOT THE SOLAR DATA:

set title "SER1CH-UA Solar Panel Data" font "Helvetica Bold,18"

  plot DataFile index 1 using ColSample:ColVolts linestyle 1 title "Solar panel voltage"
```

Figure 14.6: GnuPlot commands for plotting DvmOutputSolar.asc

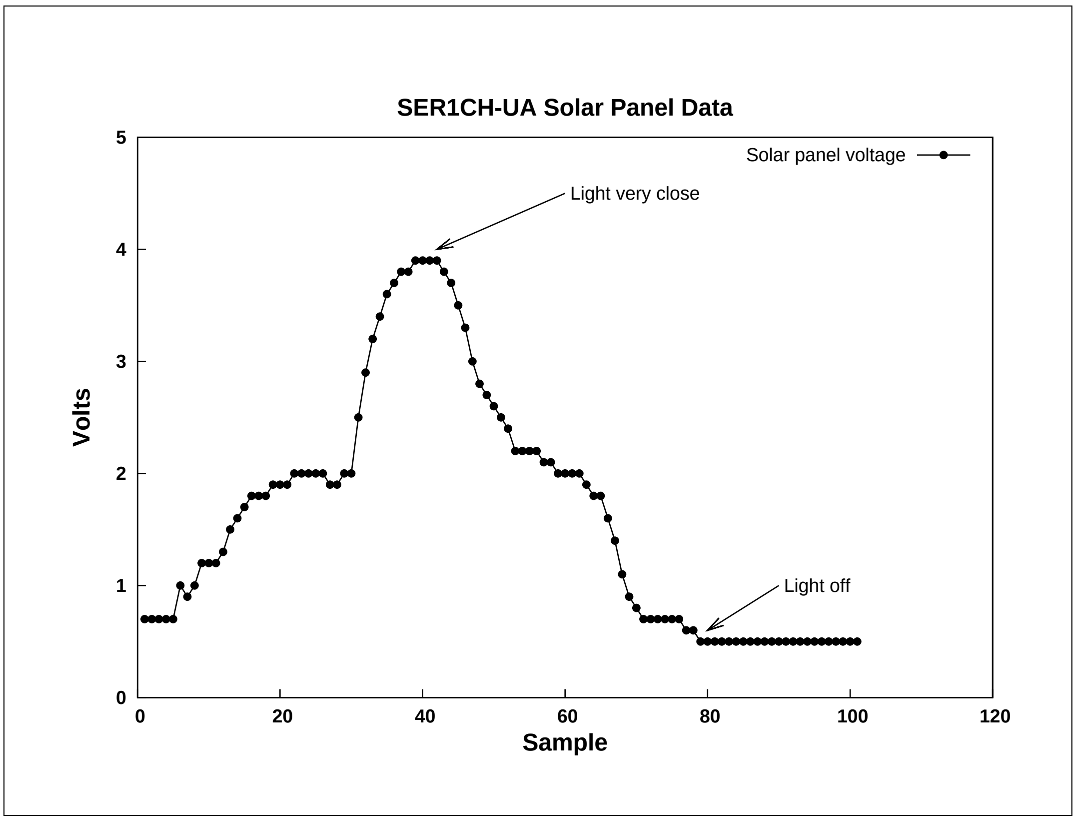


Figure 14.7: SER1CH-UA solar cell data example plot

14.3 Ratiometric potentiometer

Three wire ratiometric measurements are an excellent way to minimize errors due to temperature drift. The math behind such techniques is covered in the *Ratiometric measurements* chapter earlier in this User Manual. The demo reviewed here shows the connections for a three wire measurement using a precision 10 turn wire wound potentiometer.

For a ratiometric measurement, the A/D reference voltage provided on the red VREF banana jack should be used as the excitation voltage for the potentiometer, and the potentiometer wiper should be connected to the VIN jack. The photo below shows the connections. For a schematic, see the Ratiometric measurements chapter. Here, a 10K ohm potentiometer has been used. This means a total of 5V/10K = 0.5 milliamps is flowing through the potentiometer. This is good, it is a large enough current to avoid noise problems, but still small enough to avoid putting a high load on the VREF output.

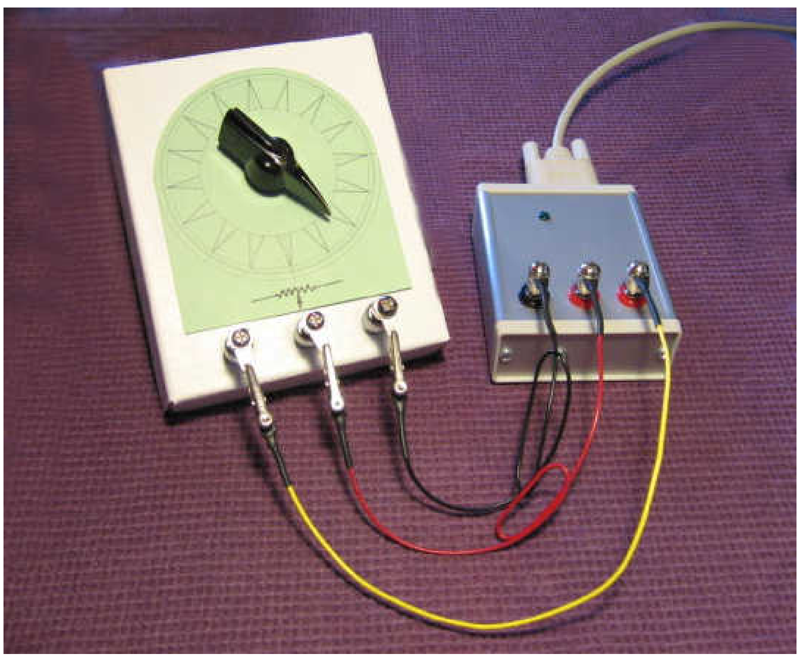


Figure 14.8: 10 turn potentiometer, SER1CH-UA connections

The connections on the bottom side of the potentiometer are simple wires to the three potentiometer terminals as in Figure 14.9. For an application of this type you may want the second DVM readout display to be calibrarted in Turns. See the ini startup file in Examples/DvmPotentiometer.ini for an example. Generating suitable custom calibration parameters is easy with the CAL program. Running CAL, first turn the potentiometer all the way to its lowest setting and take a measurement. Then do the same at the maximum number of turns and save the CAL results to an ini startup file.

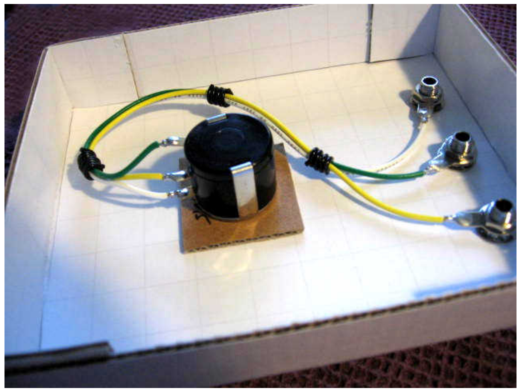


Figure 14.9: 10 turn potentiometer, reverse side connections

How well do ratiometric methods work to reduce the problems of temperature drift? With the above setup, the relative wiper voltage from the potentiometer as read by the SER1CH-UA did not vary by more than 30 microvolts (???) in our experiments. For quantitative results see the plots in the Ratiometric measurements chapter.

Potentiometers are useful for measuring angular position. However, they are only one class of sensors suitable for ratiometric use. For linear measurements, there are linear slider potentiometers. Using a linear potentiometer is the same as a 10 turn rotational device. Connect the three terminals of the linear potentiometer to the three terminals of the SER1CH-UA and you are ready. Calibrate the linear potentiometer into physical length units with the CAL program. For linear measurements over greater distances, there are also string potentiometers.

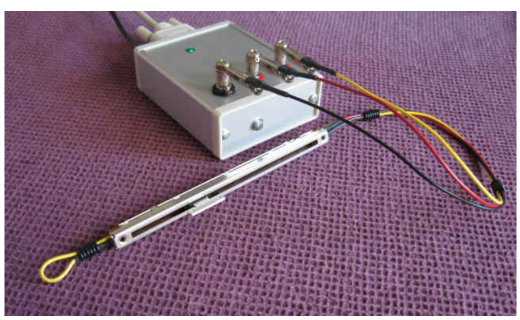


Figure 14.10: Linear slider potentiometer

For other types of passive ratiometric applications, there are also sensors such as strain gauges, tilt meters, and pressure transducers that all connect naturally to a three wire interface.

14.4 Scaling and biasing +/-10 volt signals into (0,5)

The SER1CH-UA has a full scale input range of (0,5) volts as measured with respect to its red VIN and black GND banana jacks. However, for many applications you may require a different full scale range. In particular, (-10,+10) is popular for many active sensors.

Scaling and biasing a (-10,+10) signal into the (0,5) range is fairly easy with a few resistors. This demo shows how to preform the mapping with four 10K ohm resistors. More details about scaling and biasing can be found in:

- the *Scaling active sensor voltages* chapter of this User Manual for other voltage ranges
- for additional theory, the SR application note, *Scaling and Biasing Analog Signals*

The demo circuit for (-10,+10) mapping is as in Figure 14.11:

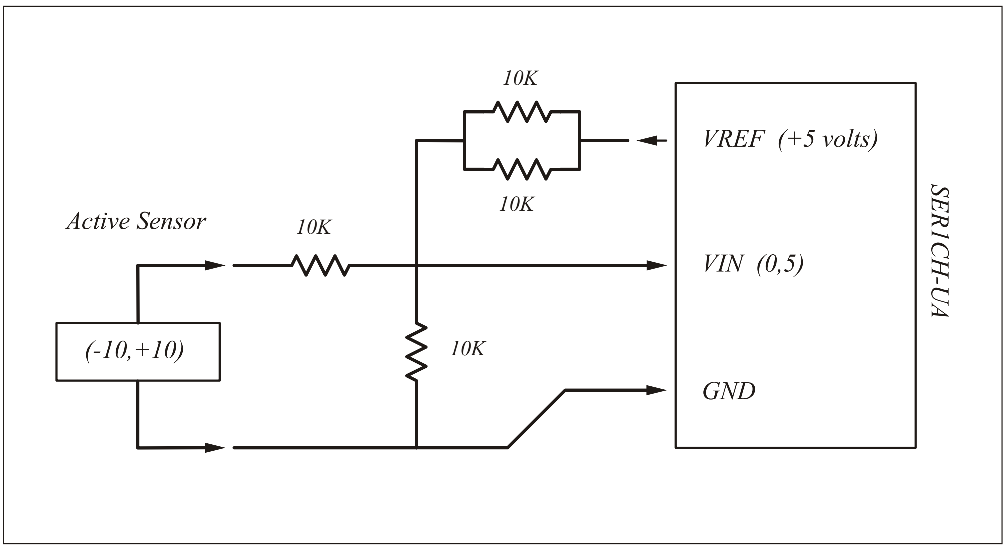


Figure 14.11: Scaling and biasing (-10,+10) with four 10K resistors

This circuit is the same as the one marked with a ⋆ star in the Figure 9.3 table in the *Scaling active sensor voltages* chapter. For this demo the 5K biasing resistor is built from two 10K resistors in parallel, since that may be all that is on hand.

There are several construction techniques for building circuits of this type. Here, we will use vector perf board, resistors with wire leads, wire, and solder. The popular white prototype punch boards are not recommended. The resistance at the punch board spring clip contacts varies considerably and is subject to corrosion. Simple solder joints result in a more reliable and stable circuit. Use good quality 1/4 watt metal film resistors for best performance.

Build the three resistor +/-10 to (0,5) divider on vector board to demonstrate one construction technique. Review soldering resistors together. Include JPEG photo. Suitable resistors are listed in the extra supplies section.

Mention resistor values can often be built using series or parallel combinations of a single stock value. So for example, with the +/-10 three resistor divider, use 4 10K resistors total, with 2 in parallel to build the 5K.

Demonstrate the input/output mapping with the scope and Gnu plots?

Make a point that a FLOATING input will not map to the 2.5 midpoint. The input must be grounded for the output to be at 2.5 ... an example that the item driving the input must be low impedance.

Also discuss where there are pads on the RevB board for smt parts. Maybe include a JPG for this too.

14.5 Measuring temperature

Reasonable temperature measurements can be made using inexpensive silicon diodes as the sensor. This example shows how to use a small signal 1N4148 diode to build a temperature sensor.

All silicon pn junctions have a change in their forward voltage of -2 mV(millivolts)/°C with changes in temperature. This thermal parameter is governed by the quantum mechanics of a pn junction and is remarkably constant across diode lots. The total forward diode voltage depends on the amount of current flowing though the diode and will generally be around 600 to 700 mV. For any given diode, if the current through it is held constant, then its forward voltage will stay the same with only the TC variation remaining. When used in this way it becomes a reasonable temperature sensor.

The SER1CH-UA can easily measure changes of 2 mV out of voltages of 600 to 700 mV, and the DVM program can be calibrated to display the result as a temperature. The key is to maintain a constant steady current through the diode. A rudimentary circuit can be as simple as:

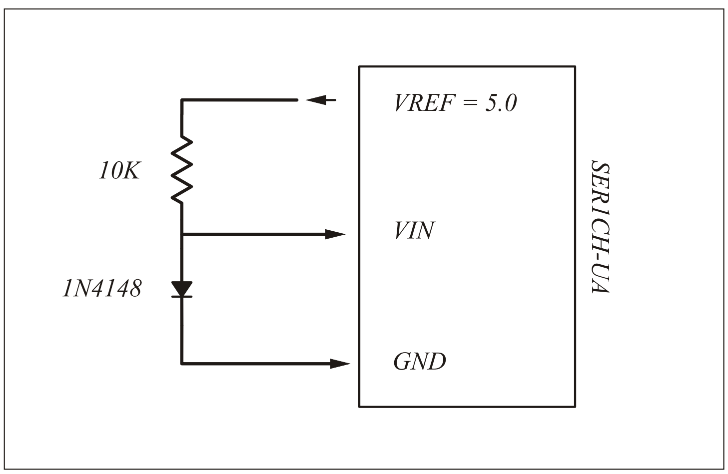


Figure 14.12: Temp diode with simple resistive current source

In Figure 14.12, the SER1CH-UA VREF is used as a 5 volt source for the diode. To a crude approximation, if the voltage across the 10K resistor is taken to be 5 volts, then an approximately constant current of 0.5 milliamps will be flowing in the diode. Of course, the current is only approximately constant because as the forward diode voltage changes with temperature the voltage across the 10K resistor changes also. Nevertheless, for many applications this is may be ok.

With the addition of an op amp, a better constant current source can be implemented as in Figure 14.13. For this circuit, the SER1CH-UA VREF is divided down to 1 volt for the

noninverting op amp input. By negative feedback the inverting terminal is also forced to be at 1 volt, and this 1 volt puts a constant current down the 10K resistor connected to the inverting terminal. Since no current flows into the inverting terminal of the op amp, the same constant current flows though the diode. The output of the amp will be at 1 volt plus the forward diode drop.

For this circuit, an LM358 or LM324 is a good generic op amp to use. These devices can even be powered in single supply fashion by VREF itself. Consuming only about 1 milliamp of power, their power requirements will not overload the VREF output. No split op amp supply is required.

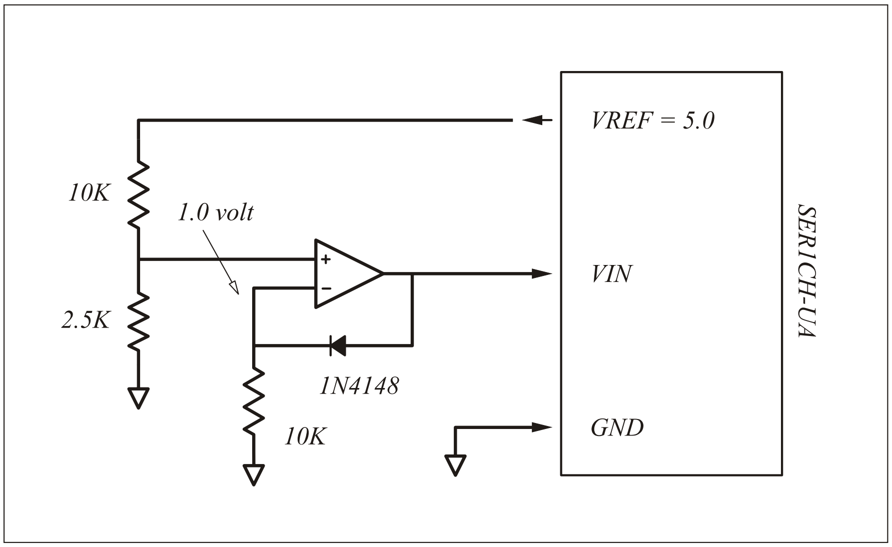


Figure 14.13: Temp diode with constant current op amp source

Many silicon diodes are suitable for use as temperature sensors. The 1N4148 or 1N914 are among the least expensive, costing as little as $0.05 even in small quantities. The pn junctions of bipolar transistors such as the 3904 or 3906 can also be used. See the Extra supplies chapter for a few vendors. More sophisticated solid state sensors optimized for temperature measurement are also available. Visit the web sites of National Semiconductor, TI, and many other semiconductor companies.

Calibrate DVM into °C or °F for a nice display on the computer screen of the temperature measured in this way ...

Chapter 15

Frequently Asked Questions

The following FAQ may help if you have general questions about the SER1CH-UA.

15.1 Software

Do you include source code ?

Yes. The source code for *all* the supplied software is included with the system at no extra cost. The software is also available for free download from our web site www.symres.com. Please *review before purchase* to make sure the SER1CH-UA is a match for your applications. Current customers should also download from the website to get any version updates.

What format are the DVM acquisition files in ?

ASCII text with the data listed in columns. The files can be read into text editors as well as imported into programs such as spreadsheets.

Two ASCII formats are possible, verbose and bare. Verbose has a header with information about the DVM acquisition parameters in addition to the data. Bare format has just the data. Besides the converted A/D data, the PC time stamp at which A/D data is acquired is optionally provided as a column.

Can I use the SER1CH-UA with Xcel spreadsheets ?

First run DVM generating an OUT data file in bare format. Then import the ASCII data file into Xcel.

Can I use the SER1CH-UA with MatLab ?

A native MatLab format is not provided. Import the DVM OUT data files in bare ASCII format.

Can I use the SER1CH-UA with Visual Basic ?

The User C Library supporting the system is available as a DLL. It can be called from Visual Basic as well as other programming languages as long as you follow C calling conventions. Please note, *SR does not provide Visual Basic programming advice.*

Can I use the SER1CH-UA with LabView ?

Set up LabView VI interfaces to the SER1CH-UA DLL library with C calling conventions and it will work. Please note, *SR does not provide LabView programming advice.*

15.2 Hardware

What analog input voltage ranges are possible ?

The analog input voltage may range from 0 to +5 volts. This is the voltage as measured on the middle red VIN banana jack with respect to the black GND banana jack. Valid count values are returned only for voltages within the specified (0,5) volt range.

If you wish to work with a different range, then you must add circuitry such as a voltage divider or amplifier to scale the voltage into the 0 to +5 range. For details, see the Scaling sensor voltages chapter. By using the VREF jack as a bias source, bipolar ranges such as (-10,+10) are easily supported.

Many passive sensors can use the VREF jack as excitation to scale their ranges naturally into the full range of the SER1CH-UA. See the Ratiometric chapter for a discussion.

Can I overdrive the VIN analog input ?

Moderate overvoltages in the range of 20 volts are ok. Input currents are limited by the signal conditioning on the SER1CH-UA front end. However, overdriving the input is hard on the system. We recommend adding suitable external circuitry to deal with the particular problems at your site rather than

making the SER1CH-UA take the brunt of the overload.

Zener diodes, TVS diodes, and gas arrestor tubes are all popular overload protection techniques depending on the size and magnitude of the problem.

Do static shocks hurt the banana jack inputs ?

Yes. Although the input circuitry has resistors and capacitors to help guard against static shocks on the banana jack connectors, static discharges are brutal to any electronics.

This includes small sparks generated from walking over a carpet. Static discharge events will result in a degradation of the electronics even if total failure does not occur.

Before touching the banana jack inputs, take a moment and discharge yourself by touching a nearby metal object such a metal desk or a computer case. Then touch the metal case of the SER1CH-UA and then finally the banana jack inputs for any connections that must be made. The moment spent consistently performing this simple routine will significantly reduce static damage.

Why does waving my hand change the DVM voltage ?

The input impedance of the SER1CH-UA is 10M ohms. Waving your hand over the input banana jacks when nothing is connected will induce a measurable charge and voltage change by capacitive coupling. DVM reflects this change.

Connect the analog input VIN to the VREF or GND jacks and you will notice that the effect disappears. This behavior is typical of all precision, high input impedance voltmeters. Floating inputs tend to wander as as various charged entities are brought near their inputs. Connect the input to specific low impedance voltages to make accurate measurements.

Can I connect a 10 ohm resistor to the VREF output ?

No. Connecting a 10 ohm resistor across the 5 volt VREF and GND would theoretically result in a current of $5/10 = 0.5$ amp flowing! Obviously, this is more current than a device like the SER1CH-UA is designed to supply.

No damage will occur by connecting a 10 ohm resistor or even shorting VREF directly to ground. The output is current limited and will supply an absolute maximum current of about 40ma. On our spec sheet lists a max of 10ma to stay within compliance. When overloaded the output will simply drop and fall out of regulation. If you need more than a few milliamps of reference current then use VREF to drive an offboard buffer.

Why is the system consuming more than 10ma ?

You probably have the green power LED enabled, which consumes considerably more than the SER1CH-UA base power consumption. The green LED jumper must be disabled to minimize power. For more information, see the Batteries and minimizing power chapter.

Is the SER1CH-UA connected to system ground ?

Yes. The black GND banana jack on the SER1CH-UA top panel is connected to the RS232 DB9 ground pin on the back panel which in turn is connected to PC ground. In addition, the outer ring of the 2.1mm power supply connector is also connected to the black GND jack. If you use a grounded power supply, then the SER1CH-UA will also be connected to that ground.

Note that even though the wall transformer supplied with the system is an unregulated *floating* power supply, or even if you use battery power, the system is still connected to the PC ground via the DB9 RS232 connection.

Is there any antialiasing filter ?

The SER1CH-UA does not have an op amp antialias filter in its front end signal conditioning. However, fow low frequency measurements 60 or 50Hz rejection is the most common requirement, and the LTC2400 A/D converter has excellent power line rejection internally. See the 60 and 50Hz power line rejection section for more information.

For rejection of higher RF frequencies, simple RC filters are usually recommended, and there are pads for installing a variety of RC combinations on the SER1CH-UA front end signal conditioning. See the Circuit diagrams.

How do I select 50Hz rejection ?

The internal LTC2400 A/D filter can be set to *either 60 or 50Hz rejection*, but not both. The selection is made with soldered on surface mount resistors on the SER1CH-UA circuit board. Usually customers in specific countries want only one setting or the other. Please specify 50Hz rejection at the time of your order if required. If not specified, the system will be set for 60Hz rejection.

Customers wishing to change the 60/50Hz setting themselves, should refer to the Circuit diagrams and the Linear Tech LTC2400 spec sheet for details.

Is twisted pair good for analog inputs ?

Yes! Even though the SER1CH-UA sigma delta A/D converter has excellent

60/50 Hz rejection, it is better to avoid power line noise in the first place. Twisted pair for the input signals is one of the best ways to do so. The long red and black test leads typically used with voltmeters create large open loops which easily pick up power line noise. Even simple steps such as loosely twisting red and black test lead pairs together can substantially reduce power line noise pickup. Jacketed twisted shielded pair round cable is even better.

Note that *foil shielding does not do much good against 60/50Hz noise*. What foil shielding does help with is to protect against ESD static discharge damage and RF noise. At 60/50Hz it is the twist that does the job.

Does the SER1CH-UA have any digital buffering ?

No, the SER1CH-UA does not have memory for buffering accumulating converted results. After a conversion, the one digital result is saved on the A/D chip and the PC must read that result. If another conversion is performed, the previous digital result is lost.

Other Symmetric Research A/D products feature sizeable FIFO buffers so the PC does not have to read the results immediately. However, at the 1Hz acquisition rates of the SER1CH-UA it is assumed the PC can keep up with the required digital bandwidth.

What kind of RS232 cable is required ?

Use a standard straight through DB9 male to female cable. Sometimes this is called a DB9MF extension cable. Do *not* use null modem cables. They swap signal wires and will not work correctly.

If you are using multiwire jacketed cable to make a custom cable, you will need 5 conductors. One each for ground, power, CTS, RTS, and DTR. We also recommend shielded cable for this connection, with the shield connected to the outer housing on the Dshell connectors on each end. The shield will conduct away any static discharges to the enclosures on each end.

Split out the power conductor and route it to the 2.1mm power connector. The other signals can go to the DB9 connector. If you are making a permanent installation consider using the SER1CH-UA-DSUB model which has all connections on Dshell connectors.

What length RS232 serial cable can I use ?

We have tried 100 feet of RS232 serial port cable. Signal quality of the digital signals was good and the system ran without trouble. Longer cables may work, but have not been tested.

Is the system opto isolated ?

No. The SER1CH-UA is connected to the ground and signal wires of the RS232 DB9. Those signals are not opto isolated from the analog ground of the SER1CH-UA.

Users requiring a floating system should use RS232 opto iosolators that support CTS, RTS and DTR, and floating power supplies such as an unregulated wall transformer or a battery.

Will USB to RS232 dongles work ?

Only dongles that support the RS232 signals RTS, CTS, DTR can be used. Be careful, many dongles support only RX and TX.

One USB to RS232 dongle we have used successfully is from Keyspan. It is clearly advertised as supporting *all* the RS232 signals including RTS, CTS, DTR. Various other dongles have failed, so don't make assumptions.

Does the SER1CH-UA record GPS time ?

Not directly. However, the DVM application program is capable of recording the PC time along with each sample. If you have a GPS receiver or NTP time setting your PC clock, then that time will be recorded in the DVM files as a result. See the *Software* chapter for more details on DVM PC time stamping.

Note that time stamps derived from the PC clock give at best millisecond accuracy. This is perfectly adequate for many applications, particularly if they are sampling at the 1Hz rate. For more precise time stamping SR has other A/D converter products with accuracy in the sub microsecond range.

Chapter 16

Extra supplies

A small collection of parts for getting started with the SER1CH-UA is included with all new orders. We will be glad to supply additional parts if you contact us.

The following list of mail order suppliers and part numbers may also be useful for obtaining small parts for use with the SER1CH-UA.

```
DigiKey
www.digikey.com
1(800)344-4539

Mouser Electronics
www.mouser.com
1(800)346-6873

JDR Microdevices
www.jdr.com
1(800)538-5000

Abbreviations used below:

  MFG = Manufacturer
  DK = DigiKey
  MO = Mouser
  JDR = JDR Microdevices
```

16.1 Small parts for cables etc

Some of the most commonly used small parts in SER1CH-UA applications are as follows. This is only a small listing of the parts and suppliers available. Many others are acceptable.

`2.1mm power plug`

```
MFG part number = CUI Inc PP3-002A
DK part number = CP3-1000A

MFG part number = Kobiconn
MO part number = 1710-2131
```

These are discrete wire power plugs suitable for soldering wires to. They are useful for connecting batteries and other custom power sources to the SER1CH-UA. Use these instead of chopping the plug off of your wall transformer.

`Alligator clips`

```
MFG part number = Mueller BU-30
DK part number = 314-1010-ND

MFG part number = Silvertronic 501793
MO part number = 835-501793
```

The Mueller BU-30 clip has a good spring and strong teeth. The connection is wire crimp, which should also be soldered for low resistance. Making cables with these clips requires skill, but they result in inexpensive connections of good quality that are easy to use. The Silvertronic part is equivalent to the Mueller.

`Johnson banana plugs`

```
MFG part number = Johnson (Emerson) 108-753-001
DK part number = J149-ND
MO part number = 530-108-0753-1
```

These uninsulated banana plugs have a 6-32 screw in the end. When plugged into the red and black jacks on the SER1CH-UA, they provide screw terminal connections.

Solder terminal lugs for Johnson banana plugs

```
MFG part number = Keystone 7329
DK part number = 7329K-ND
MO part number = 534-7329
```

The Keystone solder lugs are useful for making screw terminal connections to the Johnson banana plugs. It is also easy to clip alligators onto these lugs when they have no wire soldered on. The lugs listed above are flat. Lugs with internal tooth lock washer holes are also available for even more secure connections.

Pomona test leads

```
MFG part number = Pomona 5519A
DK part number = 501-1004-ND
MO part number = 565-5519A
```

To use these test leads with the SER1CH-UA you must trim or cut away the banana plug insulating sheath. Do this with a utility knife or razor blade carefully cutting away the plastic sheath.

DB9 molded serial port cables

```
MFG part number = generic
JDR part number = CBL-DB09-MF
```

Finished molded 6' cable. Commonly referred to as a DB9-MF male female extension cable. All pins are connected straight through. Null modem cables will not work.

DB9 solder cup Dshell connectors

```
MFG part number = generic
JDR part number = DB09P (male)
JDR part number = DB09S (female)
```

For making custom RS232 cables, solder cup DB connectors are convenient. These are available everywhere including DK and MO. The JDR parts are generic and of good quality at a reasonable price. Since the RS232 cable is MF you need one for each end.

Wall transformers

```
MFG part number = CUI Inc DPD090020-P5P-SZ
DK part number = T967-P5P-ND (9v 200ma 2.1mm plug, 110vac US)

MFG part number = CUI Inc DPD090050E-P5P-SZ
DK part number = T973-P5P-ND (9v 500ma 2.1mm plug, 220vac Euro)

MFG part number = Xicon
MO part number = 412-109024 (9v 200ma 2.1mm plug, 110vac US)
```

Don't use switching regulated wall transformers with the SER1CH-UA. No damage will occur, but switching regulators will introduce considerable high frequency noise into the system. A common unregulated linear wall transformer is generally preferable.

Single twisted pair shielded cable

```
MFG part number = Belden 9501
MO part number = 566-9501-100
```

Twisted pair provides reasonable powerline noise immunity for analog inputs. This Belden cable also has a foil shield and is jacketed. There are a large number of cable types available. This is only one example.

Double twisted pair shielded cable

```
MFG part number = Belden 9502
MO part number = 566-9502-100
```

For connecting potentiometers three wires are needed. This is the double pair version of single twisted pair. Use one wire from each pair as ground, and the other wire of each pair as signal.

1% metal film resistors

```
MFG part number = Yageo many values
DK part number = (Value)XBK-ND

MFG part number = Xicon many values
MO part number = 271-VALUE-RC
```

Metal film resistors give good performance for scaling and biasing applications. They cost very little more than carbon film parts but have better TC and noise characteristics. The parts above are standard 1/4 watt types with wire leads. For most applications, precision greater than 1% metal film costs considerably more and may not deliver substantially improved performance. Hand matching 1% metal films is a reasonable way to obtain tightly matched pairs. Hand matched carbon films will not deliver the same performance.

```
Potentiometers, 10 turn, 10K ohm
```

```
MFG part number = Vishay (Sfernice) 53411103
MO part number = 594-53411103

MFG part number = Bourns 3540 series
DK part number = 3540S-1-103-ND
```

A 10 turn pot is a simple and reasonably accurate sensor to use when testing the SER1CH-UA. Connect the three potentiometer connections to the three banana jacks with the wiper going to the red VIN jack and you can make accurate angular measurements. There are many manufacturers of 10 turn pots. A 10K ohm unit will not draw excessive current from the VREF output.

```
Potentiometers, linear slider, 10K ohm
```

```
MFG part number = Alps RSA0N11S9002
MO part number = 688-RSA0N11S9002
```

Linear slider pots do not have the accuracy of a 10 turn pot, but they are ideal for making linear position measurements. As with rotary pots you only have to connect the three terminals to the SER1CH-UA and calibrate appropriately. The above pot has a linear travel length of 120 mm = 4.7 inches.

```
Sensors, general
```

```
DK part number = Many, see their sensors listings
MO part number = Many, see their sensors listings
```

Both DK and MO have extensive selections of sensors that are suitable for use with the SER1CH-UA. Pressure, vibration, and light sensors are just a few in their listings. They can often provide an easy solution to sensor selection. PDF copies of the DK and MO catalogs are available for free download from their web sites. For many simple measurements like position or temperature, often very simple parts like potentiometers and diodes can do a perfectly good job. See the appropriate part listings here and chapters in the User Manual.

Sensors, temp diodes

```
MFG part number = Fairchild 1N4148
DK part number = 1N4148FS-ND

MFG part number = Fairchild 1N4148
MO part number = 512-1N4148
```

Virtually any silicon pn junction may be used as a temperature diode. Even the most inexpensive small signal silicon diode does a reasonable job. The generic 1N4148 or 1N914 are probably the least expensive, although if you have something else in your spare parts box it will probably do as well. More expensive solid state temp sensors are available at many of the semiconductor companies like National Semiconductor and TI.

Op Amps

```
MFG part number = TI LM324N
DK part number = 296-1391-5-ND

MFG part number = ST Micro LM324N
MO part number = 511-LM324N
```

The selection of op amps is large, each device optimizing some particular parameter. Probably the most generic part available is the LM324. The LM324 has four op amps (a quad) in a 14 pin ic package. Its close cousin, the LM358 is the same op amp, but with with two op amps (a dual) in an 8 pin ic package. These traditional bipolar devices were originally developed by National Semiconductor, but are now second sourced by many. They offer good performance at very low cost for general applications, and may be used with either single or split power supplies from as low as +5v to as high as +32v.

Batteries, 12 volt lead acid

```
MFG part number = BB Battery BP1.2-12-T1 (12v 1.2Ah)
DK part number = 522-1007-ND

MFG part number = Power Sonic (12v 1.4Ah)
MO part number = 547-PS-1212
```

The batteries above are small lead acid batteries. A good point about lead acid is they are rechargeable. A 1.2Ah battery would have enough power to run the SER1CH-UA continuously for 1.2/0.0006 = 2000 hours = 83 days.

Copper Tailings
Ruth, Nevada, 2007

SER1CH-UA User Manual

Email: info@symres.com Web: www.symres.com